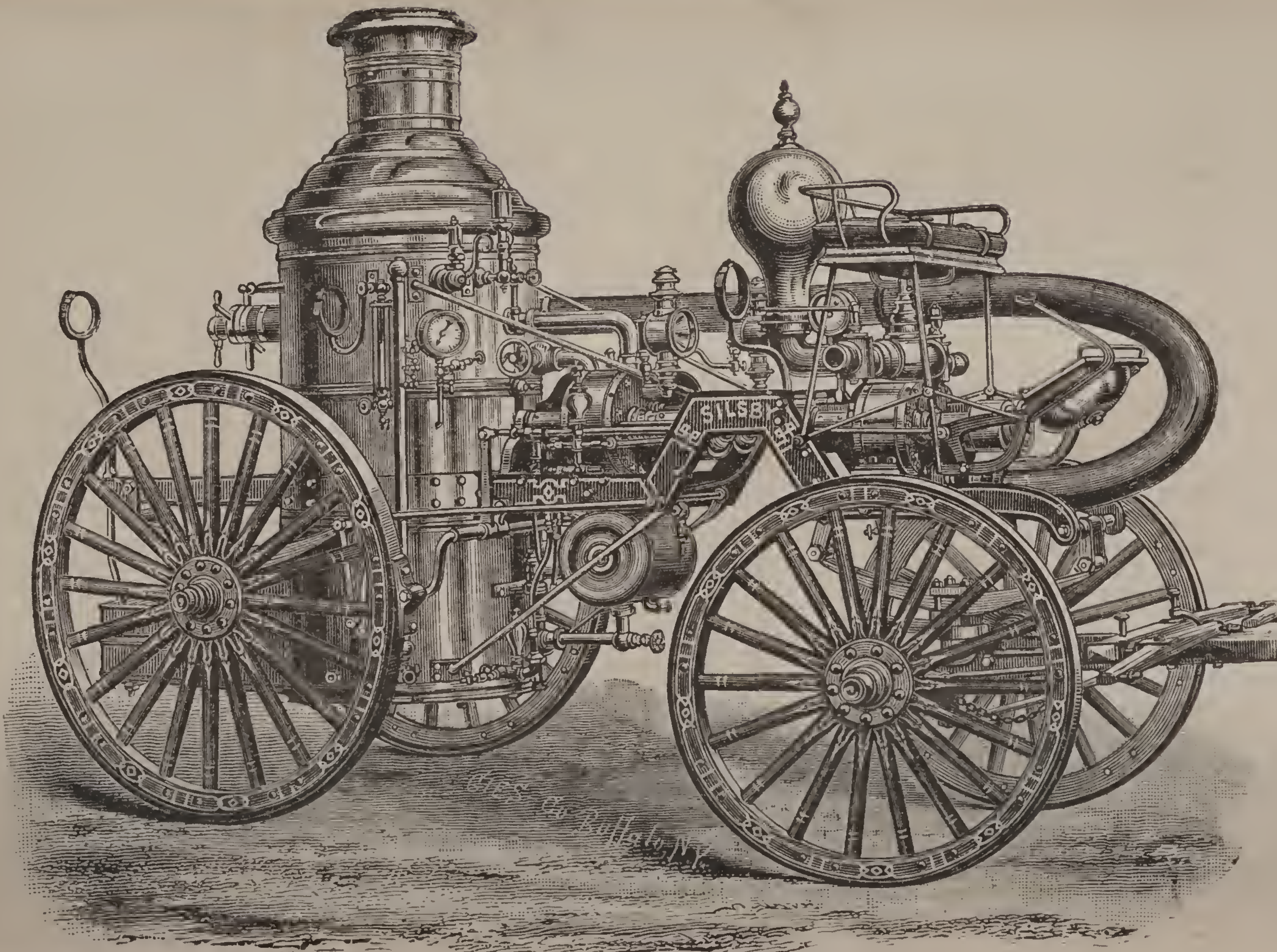

THE MODERN SILSBY.

HAND-BOOK

OF MODERN

STEAM FIRE-ENGINES,

INCLUDING THE

RUNNING, CARE AND MANAGEMENT OF STEAM FIRE-ENGINES AND FIRE-PUMPS.

BY

STEPHEN ROPER, ENGINEER,

AUTHOR OF "ROPER'S CATECHISM OF HIGH PRESSURE OR NON-CONDENSING STEAM ENGINES," "ROPER'S HAND-BOOK OF LOCOMOTIVES," "ROPER'S HAND-BOOK OF LAND AND MARINE ENGINES," ETC.

Second Edition, with Illustrations.

REVISED AND CORRECTED BY H. L. STELLWAGEN, M. H.

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TO

THE CHIEF ENGINEER,

OF THE

FIRE DEPARTMENT OF PHILADELPHIA,

THIS

SECOND EDITION

IS RESPECTFULLY INSCRIBED.

PREFACE.

A SECOND revised edition of the Steam Fire-Engine has been deemed by the publisher necessary, from the fact that much of the apparatus described in the original work have undergone material improvement in construction, designed for their betterment and greater utility in the subjugation of fires.

With reference to this particular matter, the object has been to give such corrections in construction as might seem to be most essential to the class of men for whom its publication is designed, and to weed out such descriptions as can have at this time no special interest for the reader.

That portion of the book devoted to hydraulics, as well as the pages pertaining to the properties of fire, air, water, heat and steam, remain unaltered; they play the same important part for the steam engine to-day as they did yesterday and will to-morrow.

Rules and formulæ are here for estimating the horse-power of stationary, locomotive and steam fire-engines; likewise for their care and management.

With this brief review the publisher submits this edition of the Steam Fire-Engine to the employees of the fire departments of the country, in the hope that they may glean from its pages something that will add to their efficiency, which, coupled with bravery and fidelity to the public welfare, characteristics which have ever belonged to our firemen, should gain for them that recognition which merit and faithfulness to the public interests deserve.

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A STREET SCENE,

HAND-BOOK

OF

MODERN STEAM FIRE-ENGINES.

THE STEAM FIRE-ENGINE.

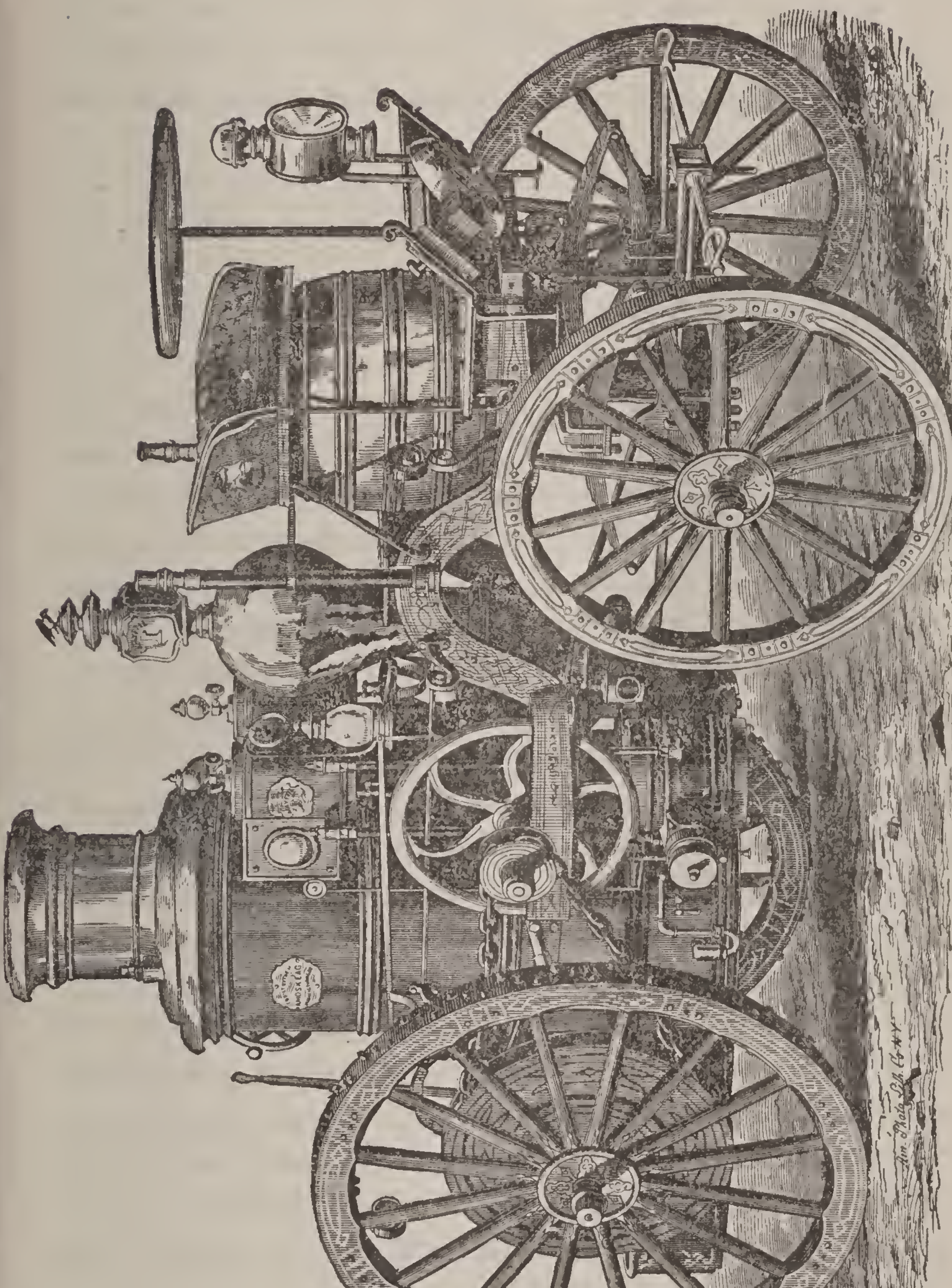
Nothing furnishes man with greater cause for congratulation, and even an excusable pride, than the feats of that mighty impersonation of brute force and human intellect — the Steam-Engine, the Hercules of the nineteenth century — which, once launched into the world's area, has gone forth, "conquering and to conquer," fulfilling its high destiny as a great civilizing agent, with an energy which no human arm can arrest and a rapidity which fills us with astonishment and admiration. It would be superfluous here to attempt to enumerate the benefits which the steam-engine has conferred upon mankind. It is a matter of universal knowledge that all branches of industry have, since its introduction into use, made most important advances through its aid; and every day's experience shows it constantly extending its beneficial influence to new and important purposes.

When we consider what the steam-engine has done in the past, we have the less difficulty in comprehending what it may be destined to accomplish in the future. The poet's anticipations have been long since more than realized —

> "Soon shall thy arm, unconquered steam, afar
> Drag the slow barge, or drive the rapid car;
> Or on wide waving wings, extended, bear
> The flying chariot through the fields of air."

There are few manufacturing processes that have not been revolutionized, simplified, and extended within the past fifty years through the agency of the steam-engine. But it is not only in the large manufactory, the splendid steamer, and the rushing locomotive, that steam shows its wonderful power and usefulness, but frequently, "Titan-like," stubbornly contending with that ruthless destroyer of man's abode — Fire. In fact, none of the multiform applications that have marked the progress of this potent creation of engineering skill has invested it with such importance as its applicability to the purposes of extinguishing fires. Its first application to this use forms an important event in the history of useful machines both in this country and in Europe.

The Steam-Engine as a Fire-Engine, is of recent origin; and contemplating the phases which it has already assumed, in connection with the fact that its energies have not yet been fully developed, it is not a matter of wonder that no other object, in the entire range of human devices, has so irresistibly arrogated to itself the devotion of the scientist and mechanic; while its complexity of parts and diversity of combination offer a wide scope for the exercise of ingenuity, highly inviting alike to the theoretical and the practical engineer.



AMOSKEAG SELF-PROPELLING STEAM FIRE-ENGINE.

FIRE.

Fire is one of the oldest elements, and one which has always attracted a great deal of attention from natural philosophers; and many theories have been advanced to account for all the remarkable phenomena which accompany it. Recent investigations, however, have proved that combustion is the result of chemical alterations in bodies of a very violent character; and that the heat thus evolved is merely an incidental phenomenon, or, in other words, heat is nothing more nor less than a vehement combination of various materials. Smoke is the product of the imperfect combustion of fuel, caused either by a want of oxygen or a want of temperature; and flame may be defined to be aëriform or gaseous matter heated to such a degree as to be luminous. The elements of all fire consists of hydro-carbons, which consist of oxygen and nitrogen. In combustion, the carbon and oxygen have so great a chemical affinity for each other, that they rush violently together, and by the force of their combustion produce intense heat. The hydrogen and nitrogen in the meantime are set free.

Fire, like the rest of the elements, when properly used and controlled, is an excellent servant and assistant to man; but, when it obtains the mastery, it is, as we find from past and continued experience, a most terrible and ruthless tyrant, destructive alike to life and property, and perfectly indiscriminate in its ravages. The palace and the hovel, the old and the young, are equally open to its destructive influence. From a death by fire or burning, all mankind, whether civilized or savage, instinctively shrink, and with good reason, for no more fearful termination can be put to the existence of man or beast than that

of burning; therefore it is the duty of all to do their best to prevent such catastrophes.

In ancient times, as well as at the present day, fires and conflagrations were constantly occurring; and many of the cities and towns of the world have at different periods been either severely injured or totally destroyed. An idea of the frequency of fires and their disastrous effect may be obtained from the following by JUVENAL, the Roman satirical poet, who lived in the first century of the Christian era:

> "But lo! the flames bring yonder mansion down!
> The dire disaster echoes through the town;
> Men look as if for solemn funeral clad,
> Now, now indeed these nightly fires are sad."

Fire was one of the most common and most destructive agents employed in ancient wars. When a city was besieged or assaulted, it was the first object with the assailants to protect their moving towers and battering engines from being consumed by fire, oil, pitch, or lighted arrows, thrown upon them from the ramparts. Every expedient that ingenuity could unfold was resorted to in the search for materials and devices to protect them; as not only the lives and property of the inhabitants, but often the destinies of armies, and even of nations, were on such occasions at stake. Men were especially trained to fire buildings, and, as they were experts in their profession, it is reasonable to conclude that the most perfect apparatus which could then be procured was employed both for destroying buildings by fire and also for preserving them.

Fires and wars have ever been deemed the most awful of earthly calamities, and, unfortunately for mankind, they have too often been united, for warriors have generally had recourse to the former to multiply the miseries

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of the latter; and in almost every age cities, like Jericho, Troy, Thebes, Carthage, and Athens, have been burnt with fire, and in many instances all the inhabitants destroyed therein. Some of the sublimest effusions of the prophets have reference to "firebrands, arrows, and death," to "blood and fire and pillars of smoke." Even in modern times warriors have proved themselves to be the greatest incendiaries, and towns and cities have been wantonly and ruthlessly destroyed to gratify their avarice or ambition. As nearly every calamity that befalls mankind is converted by some men to their own advantage, so the numerous fires in ancient times led to the detestable practice of speculating on the distresses they occasioned. Thus, many covetous persons gleaned wealth from war and fires by making it a business to buy houses that were on fire, as well as the adjacent buildings, which they commonly got at a low price on account of the fear and distress of the owners about the event. The avarice of such persons led to their own destruction in numerous instances.

Greek Fire.—The chemicals which constituted this infernal substance are among the lost arts, and consequently unknown to the chemist or scientist of the present day. But by Beckman, and others who investigated the subject, it is represented as a liquid, and was principally employed in naval combats. It was commonly enclosed in jars, and thrown on the decks of hostile vessels, and was also blown through iron and copper tubes, and "spurted," from syringes and force-pumps. Its effects on those upon whom it was thrown seem to have resembled those produced by alcohol, spirits of turpentine, petroleum or benzine, as, instead of water having the effect of quenching it, it only aggravated its fury and increased its violence.

A large fire, especially among inflammable material, is

an awful sight, and one usually as ruinous and fatal in its results as it is magnificent in appearance. In a few hours the labor of a lifetime, or even of a generation disappears, leaving in its place a shapeless, useless mass of ruins. If we possessed correct statistics of the number of fires, their causes, the value of property destroyed, and the number of lives sacrificed, it would present a most appalling record, the calm study of which would scarcely fail to make people both wiser and more careful in their dealings with this destructive element.

It is a noteworthy fact, that up to the present time, the tendency of fires is to become more numerous, of far greater extent than formerly, and to cause more severe losses; whilst the means of controlling them does not seem to increase, even though the steam-engine has been successfully employed as an assistant. This goes to show the necessity and importance of having the origin of every fire thoroughly investigated. It has been established, both by experience and observation, that fires have a tendency to outstrip the population in all large cities, and rapidly increasing communities, which would warrant the conclusion, that a population distributed over several towns is less liable to outbreaks of fire than the same population brought together within the compass of one town. To explain this social phenomenon, it may be claimed, that it arises from the great density of the population in large towns compared with that of small ones; though, on the other hand, it might be asserted that this very density was an element of protection; as in a populous district, fires would be more liable to be discovered in their incipient state.

There are circumstances connected with the furnishing of houses, the storage of goods in houses and elsewhere, and the general hurry and pressure of metropolitan life, which

involve contingencies more favorable to the occurrence of fires than are likely to be found in many country towns. There is also the circumstance that large cities have large buildings, so that fires in such localities are liable to be not only numerous, but extensive.

Fires in numerous instances are said to be accidental, but on investigation it would be found, in most cases, that they were the result of sheer carelessness, and owe their origin to such agencies as kindling fires with oil, allowing the flues of heaters to come in contact with the woodwork in buildings, or the ends of joists to communicate with chimneys, the employment of candles or other naked flames in buildings where petroleum, camphene, benzine, gasoline, spirits of turpentine, etc., have been stored, or are transferred from one vessel to another for the purpose of sale or carriage. Reading in bed, friction matches left within the reach of mice, or lighted pipes and cigars being brought in close proximity to combustible and inflammable material, are also the source of many a conflagration. Placing stoves on sheet-iron, without any non-conducting substance between it and the floor to hinder the heat from passing into the wood, may be added to the list. Such carelessness amounts to wilful negligence, and ought to be subjected to the same penalties as incendiarism, for which reason, from the earliest ages, we find provision made for restitution or punishment, according to the origin of the fire.

Incendiary fires are more difficult to deal with than accidental ones. Although the law is very severe whenever an incendiary is discovered, still, as long as there is thought to be sufficient inducement to compensate for the risk, such fires will occur; but it is also highly probable that the setting on foot of a strict investigation into the causes of all fires will considerably circumscribe the work of the

incendiary. All laws for the punishment of incendiarism ought to be enforced with rigorous severity, as no punishment is too severe for the execrable wretch who would wantonly endanger the lives of his fellow-beings, or doom hundreds of needy people to poverty and distress by destroying their means of support. Wilfulness and carelessness are the two best allies of the fire-king, through whose influence he often exceeds his bounds.

Fires can never be entirely prevented, as the causes of their origin are so numerous and varied ; and as in all large cities and manufacturing communities there is a constant exposure to fire, in consequence of much of the material and manufactured products being of an inflammable character, to drive out these manufactures would be tantamount to the population going out themselves, because, when any community ceases to encourage and protect manufacturing interests, they cease to be important; or when they determine upon absolute safety, they must either cripple or materially interfere with some of the most valuable and productive industries. Instead of so doing, it is their duty to be more vigilant and careful in investigating the causes of all fires, and in the general diffusion of knowledge relating to certain materials and processes, and in this way to determine how such occurrences may be guarded against in the future.

Strange as it may seem, it is nevertheless a fact, that the lesson taught by terrible conflagrations has very seldom any durable results, as the experience of Portland, Boston, Baltimore, and Chicago taught no new moral, and was soon forgotten, at least by builders. After a devastating fire has baffled all attempts to resist it, the makers of iron safes are stimulated to devise something more secure than was before known. After a burglary of more than usual skill, another order of ingenuity is set to work to oppose

more successfully the drill, the chisel, the crowbar, and the sledge-hammer; and the locksmiths are expected to do their own part of the work by producing fastenings that will defy picking and resist explosives. But with builders and owners of property the case is quite different, as, after disastrous fires, things soon drop into the same old ruts as before; in fact, it is very rare that any voluntary improvements result from the experience so expensively purchased. For this reason provision should be made in all building laws, that any owner, architect, builder or workman who would wilfully violate, or even negligently fail to comply with the provisions of the law, should be held responsible, and subjected to penalties in accordance with the degree of culpability.

PRECAUTIONS AGAINST FIRES.

In case of fires occurring in dwelling-houses where the inmates are awake, there can be no reason to doubt that, if some simple and ready means of suppressing the fire at its first start were at hand, and used immediately with energy, many of the disastrous conflagrations which are of daily occurrence might be averted; but, unfortunately, as a general rule, too much faith is placed in the ability of others, and too little in ourselves; consequently, we fail to provide ourselves with some ready and simple means of suppressing the fire in its early stages, and thereby run the risk of the destruction, in many cases, of valuable property. A bucket or two of water thrown on a fire on its first discovery, will in many instances extinguish it; but if not done quickly and promptly, it may require thousands of gallons, or even tons of water to put it out. It is too much the custom to neglect to provide against the chances of fire, simply for the reason that parties never had a fire

occur in their house, or on their premises. Did the parties alone who neglect to provide against fires, experience its terrible ravages, it might be said that, to a certain extent, they deserved it; but unfortunately, in many instances, such fires extend to others, who were both prudent and cautious in guarding against fires, and who are ill able to bear its ruinous effects.

Very few property or factory owners make adequate provision for extinguishing fires that may occur on their own premises; and even if they do, such apparatus is generally capable of rendering very little service. Though it might originally be very efficient, when allowed to fall into disuse, as often happens, it becomes worthless. Long immunity from the ravages of fire generally causes a diminution in the attention bestowed on fire-engines and appliances provided for its suppression, and it frequently happens, when required for use, that the machines in which the utmost reliance was placed are found to be nearly useless. Instead of this state of affairs, no pains should be spared to excite and keep up an active interest in all kinds of apparatus provided for the extinguishment of fires. Machines of any kind, if allowed to fall into disuse, deteriorate more rapidly than if frequently used. None but the best class of machines should be provided for extinguishing fires, and they should be kept up to the highest point of efficiency, regardless of cost, and be in the hands and under the control of persons capable of using them in case of an emergency.

The first cost of providing reliable and efficient means for the controlling and extinguishing of fires, should be esteemed a secondary consideration, seeing that the existence of such means, especially if available when wanted, and of the required power to prevent a fire from extending and becoming unmanageable, will in almost every

case more than repay their original cost. The right way, perhaps, to reconcile the cost of providing valuable fire apparatus, for either public or private use, would be to look at the damage done by a terrible fire, in a case where means had not been provided for extinguishing it; or, if provided, were found to be inefficient or worthless, and then feel that, had the means been provided and kept in proper order, all that loss might have been prevented.

Even when ample and efficient apparatus has been provided for extinguishing fires in factories, stores, and warehouses, they are, in many instances, incapable of rendering any service, in consequence of being injudiciously located. Fire-pumps or fire-extinguishers of any kind should never be placed where they would be liable to be consumed in the early stages of a fire, or where access to them may be cut off, or where, in consequence of the heat and danger induced by the fire, it would be impossible to manage them. Any machine or apparatus intended for extinguishing fires should be placed outside of the buildings or property which they are intended to protect.

WHAT TO DO IN CASE OF FIRE.

The hurry and excitement incidental to the sudden outbreak of a fire, and the almost universal want of presence of mind and judgment caused thereby, are no small additions to this terrible and often fatal calamity. PHIN, in his excellent little work on accidents, says, "Few things have been more praised than presence of mind;" and certainly there is nothing that is more to be desired in case of accident. The person that keeps cool can always be depended upon to render efficient assistance; while he who is liable to become excited and get into a hurry, can never hope to be of any use. Slowness and hesitation are to be

condemned quite as much as hurry and excitement. It is deliberate haste that is needed. The work that is done in a hurry is not done at all; for it is done in such a bungling manner that it will generally have to be done over again, thus involving the loss of much valuable time, and frequently much suffering. For these reasons, every one who would cheerfully render assistance to others in case of accident, should learn how to keep cool.

The most powerful means of enabling any person to keep cool under trying circumstances, is a thorough knowledge of what is to be done. The person who knows exactly what to do is, by virtue of his or her knowledge, perfectly self-reliant. They therefore find no difficulty in keeping cool; for hurry and excitement arise, in a large measure, from ignorance and anxiety. Therefore every person should be well acquainted with the various modes of escape, both above and below, which are offered by the dwelling in which he resides. If a trap-door leads to the roof, a step-ladder should be permanently affixed thereto, as otherwise it will be liable to be out of the way when wanted. Some simple and reliable fire-escape should also be provided, and always kept in one convenient and accessible place; and every member of the family, or inmate of the building, should be made well acquainted with the most safe and reliable mode of using it.

When a fire breaks out at night, it is always best, if the danger be imminent, for persons not to stop to dress, but to wrap themselves in blankets or quilts, and avail themselves of the most convenient means of escape, being particular, in all cases, to close the doors after them.

If persons are surprised while asleep, and on waking up find the room filled with smoke, it is always best, in their efforts to escape, to crawl on their hands and knees on the floor, as the smoke and hot air ascend. and is more

dense at the ceiling than at the floor. If the smoke is very suffocating, a piece of flannel, woollen shirt, or dress held over the mouth and nose, will protect the lungs from injury and prevent suffocation.

If escape from the doors on the first floor and the trap-door on the roof be cut off, and no fire-escape at hand, it is always best to hurry all the inmates to the room least affected by the smoke and hot air, and hurriedly make a rope of sheets and bedding, attaching one end of it to a bed-post or bureau-leg, and by this means descend to the ground. Persons should never jump or precipitate themselves from windows, unless they are satisfied that all other means of escape are unavailable; and should this become the only alternative, persons on the outside should hold a carpet or blanket, or even a fireman's or policeman's coat, for the person to jump on, so as to prevent loss of life or serious injury.

If a person's clothing takes fire, wrap a blanket or quilt around them quickly, for the purpose of excluding the air and smothering the fire. Woollen goods are preferable under such circumstances, as they are less combustible than cotton; but in no case allow them to run out of doors or even in a draught, as the oxygen of the air intensifies the combustion, and of course causes the fire to burn more fiercely.

MEANS OF PREVENTING FIRES.

All cities should have a restriction limiting the height of the buildings by the width of the streets, unless the exposures are properly guarded. In all large towns and cities, every new building should be planned and constructed with reference to the use to which it is to be applied.

All roofs should be required to be constructed of non-

combustible materials in all cases where buildings are over eighteen feet high.

Certain provisions against the origin and spread of fires should in all cases be required in the construction of dwelling-houses and stores.

All chimney-flues should be properly plastered on the inside, and the brickwork of proper thickness between the flue and the floor or studding.

Instead of laying brick or stone on the planks to form hearths, they should be supported by brick arches.

In putting in hot-air flues and registers, the precaution should be taken, to give a space of at least two inches between them and the nearest woodwork (four inches would be better); this space should be filled with some good non-conducting substance, such as soapstone or asbestos. In stores and factories, hot-air flues, radiators, and steam-pipes should be placed at a safe distance from all woodwork, as they are prominent causes of fires when they are brought in close proximity to dry wood.

As stairways, light-holes, and hoistways render the greatest facilities for the spread of flames when once started, the only effective way to overcome such danger is to enforce the necessity of closing them.

All hatch- or hoistways should have doors of iron, or some other fire-proof material.

Whenever studded partitions are used in the construction of buildings, the space between the studs and the lathing should be well filled with bricks and mortar, for at least two feet above each floor. This will prevent the fire from running up between the studding and igniting the floors above.

Every city and town should have strict laws prohibiting the storage of inflammable materials in thickly populated districts, or in locations where, in case they should become

ignited, they would endanger both life and property. There can be no reason why such materials should not be kept by themselves, in locations isolated to a certain extent from other buildings, and have sewers, drains, or ditches forming a communication between the buildings in which they are stored, with some river or brook, so that in case of fire or explosion, the burning oils, liquids, or spirits might pass off, and thereby prevent fearful destruction of property.

DIFFERENT METHODS OF EXTINGUISHING FIRES.

Numerous attempts have been made at different times to increase the efficiency of water by chemicals, for the purpose of extinguishing fires; and also to extinguish fires "chemically" by means of ammonia, or *carbonic acid gas*, etc., which can be used either dry or mixed with water or steam. But the idea, like many others, though sound in theory, is unfortunately not so in practice, as, when we see magnificent blocks of buildings lapped up as though it were by the tongue of the fire-fiend, and cities nearly obliterated by the ruthless destroyer, in defiance of the most energetic and heroic efforts of the best-trained fire-brigades and the most powerful and efficient steam fire engines, the fanciful theories of the laboratory are apt to vanish.

Still, some of these fire-annihilators possess merit, as they are always ready for use. All that is necessary to do is to take up the vessel, and direct the gas upon the burning matter, which will, in most instances, check its progress even more speedily than water applied with a bucket. Wilcox's and Connelly's patent fire-extinguishers—the former portable and the latter stationary—are said to have rendered efficient service in extinguishing embryo fires; but to rely on such contrivances for extinguishing fires in general would be very unwise.

The Wilcox Annihilator, though very efficient, is, in consequence of being portable, or capable of being managed by one person, very limited in its supply of gas, and of course unfit to cope with any formidable fire. The Connelly extinguisher being stationary, can be made of such proportions as to furnish an almost unlimited supply of the gas; and the pipes for its delivery may be protected from accident by carrying them underground, like any ordinary steam- or water-pipes. And such is the force of the gas issuing from these powerful machines, that it produces a current like that in the injector, which is capable of lifting water several feet from a well or main; although, according to the natural order of things, water and the steam fire-engine must ever be looked upon as the only reliable means of checking the progress of fire when once fairly started. Still, property owners, and people in general, should be made better acquainted with the use and management of fire-annihilators.

The principle involved in the extinguishing of fires is precisely the same, whether "carbonic acid gas" or water is used; the "gas" shuts out the oxygen of the air from the combustible substance by acting as a covering to it; but, like steam, it can act only on the surface, and consequently can absorb but little of the heat. Water has the advantage of being capable of entering the combustible mass, which, on being converted into steam, takes away much of the heat, and therefore lessens the combustion; of course, the cooler the water is, the more serviceable it is: but even hot water is more effective than "carbonic acid gas," as it enters the fire, and, in consequence of not being as hot as the fire, takes away part of the heat.

Steam is now very successfully employed as a fire-extinguisher in mines, and situations where it can be confined. It has the effect of driving out the air, and

consequently the oxygen which supports the fire; and when it comes in contact with the ignited materials, it has the effect of quickly cooling off the surface; but as it can only act on the surface, it is evident that the interior of the heated mass can cool but very slowly. In confined situations, such as mines and close apartments, it is capable of smothering the fire, and thereby holding it in check until a fire-engine, or some other appliance, can be brought into a position to play on it. Steam is very efficient in extinguishing choke-damp in mines, and also in condensing the smoke arising from fires in shafts and slopes.

FIRE-ESCAPES.

Nearly all the forms of fire-escapes used in modern times, or even at the present day, are similar to those employed by the ancients for the purpose of scaling walls and entering fortresses in time of war, etc.; and it is reasonable to suppose that the same devices by which persons entered buildings would be employed for escaping from them. As the utmost ingenuity of the ancients was exercised in devising the means to accomplish the one, it is exceedingly natural that modern inventors should hit upon similar contrivances to effect the other.

Fire-escapes in ancient times embraced a great variety of forms, among which were ladders, rope and leather, and also folding ladders of wood and metal,—some of the latter consisting of numerous pieces screwed in each other by the person ascending, till he reached the required elevation. Others with rollers at their upper ends to facilitate their elevation; baskets or chests containing several persons, raised perpendicularly on a moving frame by means of a screw below, that pushed out several hollow frames or tubes contained within each other, like those of a tele-

scope, whose united length reached to the top of the place attached; sometimes men were elevated in baskets suspended at the long end of a lever or swape.

The subject of fire-escapes is a very important one, and one which should occupy the attention of legislators and all those who take an interest in the lives of their fellow-beings. There is no reason why proprietors or occupants of high buildings should not be compelled to provide means of escape for their employees in case of fire, than that owners of steamships should be required to make provisions for the safety of their passengers in case of accident.

The invention and improvement of fire-escapes have not received in the past that attention from inventors and ingenious mechanics that has been devoted to contrivances of far less importance. What is needed is a cheap, convenient, and reliable fire-escape, one that could be easily managed by either man or woman; such a contrivance could not fail to amply remunerate its inventor.

FIRE-PROOF BUILDINGS.

The construction of fire-proof buildings has long been a favorite idea with architects and owners of property, and one on which no small amount of thought has been bestowed; but the recent terrible conflagrations at Baltimore, Boston, and Chicago demonstrated the fact that no building yet constructed is safe from the ravages of fire, if it contains inflammable materials, even though it may be constructed in the most substantial manner. It is a noteworthy fact, that many of the most destructive fires that have occurred in this country of late years, originated in so-called fire proof buildings; and instead of offering any safeguard to the goods they contained, they

proved to offer an obstacle against the speedy extinguishment of the fire.

Scientific men have been unable, up to the present time, to discover any material capable of withstanding the ravages of fire. This arises from the fact that there is no known substance in nature that is incombustible, or that is not influenced by heat and cold. Stone splits and crumbles under the combined action of heat and water; brickwork, even of the most substantial character, when exposed to the extreme heat of large fires, bulges and cracks, and even crumbles to dust; iron, whether wrought or cast, when exposed to high temperatures, expands, and either pushes or pulls down the buildings of which it was intended to be the main stay.

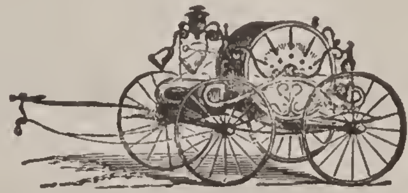
Though the desirability and importance of fire-proof buildings cannot for a moment be denied, yet experience has shown that the most scientifically constructed and substantial buildings are as frequently doomed to destruction as those of a less expensive character. Now, in view of the foregoing facts, the question would naturally be asked, is there any real safety from fires? and the answer would be, that while it is wise and prudent to construct all buildings in a safe and substantial manner, immunity from fire does not depend so much on the character of the building, as it does on the vigilance and watchfulness exercised in preventing it.

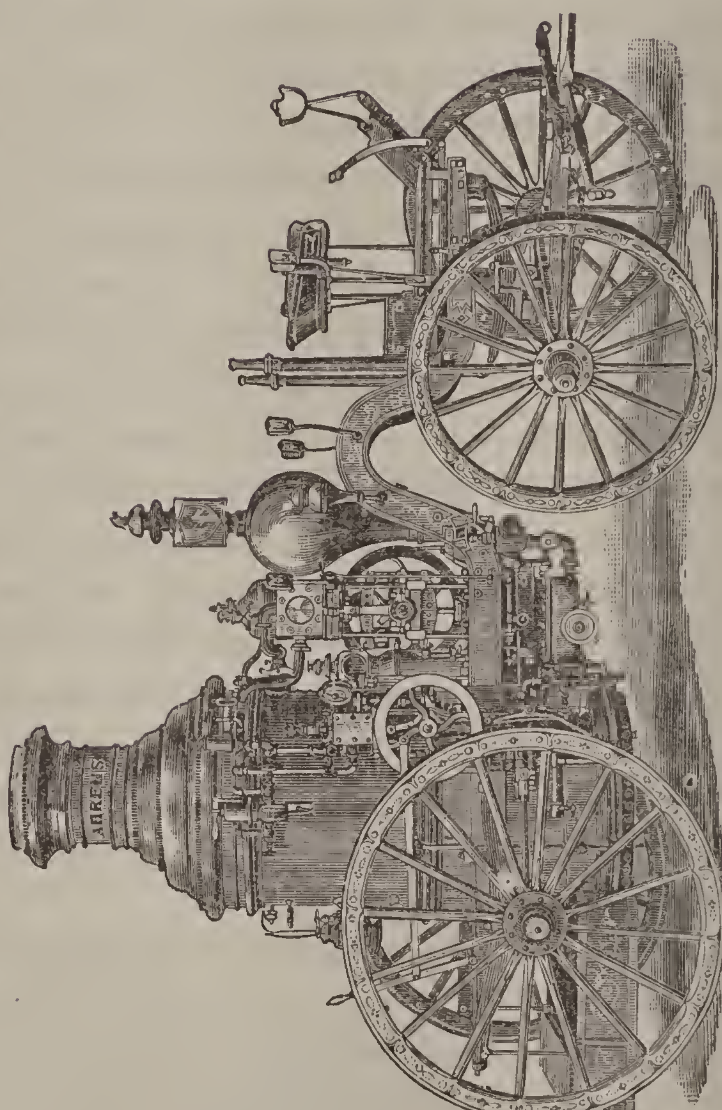
LOSSES BY FIRE.

When buildings are burned, the remark is frequently heard that they are covered by insurance, and that the proprietors or owners of a building or factory will receive nearly its equivalent, or have the building restored, which will incur only a temporary loss; but this is a narrow view

to take of the subject, as it does not take into account the losses and sufferings caused by the suspension of business, resulting in the throwing out of employment, in many instances, thousands of hands, and perhaps ending in failure, or even bankruptcy. In such cases the evil falls on the least able to bear it, namely, the workers or employees, as they are deprived frequently for a long time, owing to the confusion incident to such disasters, of an opportunity of earning the means of subsistence, and are in many instances reduced to great poverty and suffering.

It is very seldom that buildings are insured to anything like their full value, consequently the interruption of business, the difference between the value of property destroyed and the amount of insurance, entail a far greater loss to any community than the advantages to be gained by the reconstruction of the building. Therefore it is the duty of all to be vigilant in guarding against fire, as industries of every description are so interwoven in their relations, that the loss sustained by one class of business men, manufacturers, or mechanics, affects the whole.





AHRENS' STEAM FIRE-ENGINE.

AHRENS' STEAM FIRE-ENGINE.

The cut on the opposite page represents the celebrated Ahrens Steam Fire-Engine, manufactured by the Ahrens Mfg. Co., of Cincinnati, Ohio. The boiler of this engine is an upright; but, with that exception, it differs from any other ever used for the same purpose. It consists of a steam- and water-space, which forms the fire-box, inside of which is securely fastened a coil, through which the feed-water is forced; thus giving an abundance of heating surface, without any danger of burning the parts most exposed to the fire; and as the coil has plenty of room in which to expand and contract, it obviates the evils resulting from undue strains induced by unequal expansion and contraction. The water is supplied to the coil by a pump, which makes a forced circulation — this being the quickest way known to make steam; and has the additional advantage of never allowing any sediment or scale to collect in the tubes, which must necessarily increase the durability of the boiler. The shells are cylindrical, and are made of the best steel-plate and the most excellent workmanship. They are very efficient, as steam can be raised on them from cold water in from three to four minutes.

The engine is upright, double-acting; the steam-cylinder resting on columns which are attached to the frame and to the boiler, and form supports for the crank-shaft bearings. The frame encircles the boiler on each side, extending as far as the forward axle in front, and forming a support for the fuel-box in the rear. The pump is attached to the frame in front of the boiler, and is very conveniently arranged, as by taking off the bottom plate the valves can be taken out, either for examination or repairs, without any trouble. The receiving-screw is located in the pump-bottom, near the boiler, to which the

suction hose is always attached. The discharge gates are in front, directly under the air-vessel.

A new and very important feature of this engine is the air-pump, which is used for keeping the air-vessel constantly supplied with air, which has the effect of rendering the hose quite steady when the engine is working. The Ahrens' steam fire-engines have an excellent reputation for durability, efficiency, and economy. They are in very general use in the Western States, and give entire satisfaction. Each engine is furnished with a full supply of the most improved and necessary attachments.

AIR.

The atmosphere is known to extend at least 45 miles above the earth. Its aggregate weight has been calculated at upwards of 77,000,000,000 of tons, or equivalent to the weight of a solid globe of lead 60 miles in diameter. Hence this enormous weight reposes incessantly upon the earth's surface, and upon every object — animate or inanimate, solid, liquid, or aëriform. 100 cubic inches of air, at the surface of the earth, when the barometer stands at 34 inches, and at a temperature of 60° Fah., weigh about 31 grains; being thus about 815 times lighter than water, and 11,065 times lighter than mercury.

The component parts of the air are about 79 measures of nitrogen gas, and 21 of oxygen; or, in other words, air consists of, by volume, oxygen, 21 parts; nitrogen, 79 parts. By weight, oxygen, 77 parts; nitrogen, 23 parts.

Now since the air is possessed of weight, it must be evident that a cubic foot of air at the surface of the earth, has to support the weight of all the air directly above it; and that, therefore, the higher we ascend in the atmosphere the lighter will be the cubic foot of air; or, in other words, the farther from the surface of the earth, the

less will be the density of the air. At the height of three and a half miles it is known that the atmospheric air is only half as dense as it is at the surface of the earth.

From the nature of fluids, it follows that the atmosphere presses against any body with which it comes in contact—because fluids exert a pressure in all directions—upwards, downwards, sidewise, and oblique. Its particles are so inconceivably minute that they enter all substances — even liquids. It penetrates all the ramifications and innermost recesses of porous bodies, and is mixed up with and circulates in the blood of men and animals; and, by the pressure of its superincumbent strata, it is urged through almost every substance. It is this circulation through the interior of the bodies of men and animals which counterbalances its outer pressure; because, if its weight were not neutralized, neither man nor beast could walk, and would be as mute as statues of lead, as the lips once closed could never again be opened.

The amount of pressure of a column of air whose base is one square foot, and whose altitude is the height of the atmosphere, has been found to be 2156 pounds, avoirdupois, or very nearly 15 pounds of pressure on every square inch. Consequently, it is common to state the pressure of the atmosphere as equal to 15 pounds on the square inch. If any other gaseous body or vapor — such as steam — exerts a pressure equivalent to 15 pounds on the square inch, then the force of that vapor is said to be equal to one atmosphere. If the vapor be equal to 30 pounds on every square inch, then it is equal to two atmospheres, and so on; consequently, the atmospheric pressure is capable of supporting about 30 inches of mercury, or a column of water 34 feet high.

It is known that the pressure of the atmosphere is not constant, even at the same place. At the equator, the pressure is nearly constant, but is subject to the greater

change in the high latitudes. In some countries the pressure of the atmosphere varies so much as to support a column of mercury so low as 28 inches, and at other times so high as 31, the mean being 29.5; thus making the average pressure between 14 and 15 pounds on the square inch. But in scientific books, generally, the pressure is understood, in round numbers, to be 15 pounds; so that a pressure exerted equal to 1, 2, 3, 4, etc., atmospheres, means such a pressure as would support 30, 60, 90, 120, etc., inches of mercury in a perpendicular column, or 15, 30, 45, 60, etc., pounds on every square inch.

The pressure of the air differs at different altitudes, *e.g.* at 7 miles above the surface of the earth the air is 4 times lighter than it is at the surface; at 14 miles, it is 16 times lighter, and at 21 miles, it is 64 times lighter. It requires 13.817 cubic feet of air to make one pound; consequently, one cubic foot of air at the surface of the earth weighs 527 grains, or ¼-ounce, avoirdupois; but under a pressure of 5½ tons to the square inch, air becomes as dense, and would weigh as much per cubic foot, as water.

TABLE

SHOWING THE WEIGHT OF THE ATMOSPHERE IN POUNDS, AVOIRDUPOIS, ON ONE SQUARE INCH, CORRESPONDING WITH DIFFERENT HEIGHTS OF THE BAROMETER, FROM 28 INCHES TO 31 INCHES, VARYING BY TENTHS OF AN INCH.

Barometer in Inches.	Atmosphere in Pounds.	Barometer in Inches.	Atmosphere in Pounds.	Barometer in Inches.	Atmosphere in Pounds.
28.0	13.72	29.1	14.26	30.1	14.75
28.1	13.77	29.2	14.31	30.2	14.80
28.2	13.82	29.3	14.36	30.3	14.85
28.3	13.87	29.4	14.41	30.4	14.90
28.4	13.92	29.5	14.46	30.5	14.95
28.5	13.97	29.6	14.51	30.6	15.00
28.6	14.02	29.7	14.56	30.7	15.05
28.7	14.07	29.8	14.61	30.8	15.10
28.8	14.12	29.9	14.66	30.9	15.15
28.9	14.17	30.0	14.70	31.0	15.19
29.0	14.21				

A column of atmosphere 45 miles high, and one square inch in area, just balances, and consequently weighs the same as a column of mercury of like area and 30 inches high. This column of air also balances $33\frac{7}{8}$ feet of water. Consequently, a column of air 45 miles high, 30 inches of mercury, and $33\frac{7}{8}$ feet of water, weigh the same.

Suppose it were possible to erect a tube having a sectional area of one square inch upon any part of the earth, and that this tube be long enough to reach up to the height of the atmosphere (which is supposed to be about 45 miles), the air contained in such a tube would weigh about $14\frac{3}{4}$ pounds. Now, if we take another tube, having the same sectional area, and place $14\frac{3}{4}$ pounds of water in it, the level of the water will be found to be $33\frac{7}{8}$ feet above the bottom of the tube. If we take still another tube of the same area, and place $14\frac{3}{4}$ pounds of mercury in it, the level of the mercury will stand 30 inches above its base.

1 atmosphere, or 15 pounds per square inch,	= 30 inches of mercury.
Each pound pressure per square inch	= 2 inches of mercury.
Each pound pressure per square inch	= 1 inch rise on siphon-gauge.
1 atmosphere, 15 pounds per square inch,	= $33\frac{7}{8}$ feet of water.
Each pound pressure per square inch	= $27\frac{1}{10}$ inches of water nearly.

Air, like all other gases, expands but one volume for each 493° of temperature through which it is raised, and in order to double its volume, we must raise it 493° more, which will bring it to a temperature of 986° Fah.

TABLE

SHOWING THE EXPANSION OF AIR BY HEAT, AND THE INCREASE IN BULK IN PROPORTION TO INCREASE OF TEMPERATURE.

Fahrenheit.			Bulk.	Fahrenheit.			Bulk.
Temp.	32	Freezing-point.	1000	Temp.	75	Temperate......	1099
"	33	"	1002	"	76	Summer heat...	1101
"	34	"	1004	"	77	"	1104
"	35	"	1007	"	78	"	1106
"	36	"	1009	"	79	"	1108
"	37	"	1012	"	80	"	1110
"	38	"	1015	"	81	"	1112
"	39	"	1018	"	82	"	1114
"	40	"	1021	"	83	"	1116
"	41	"	1023	"	84	"	1118
"	42	"	1025	"	85	"	1121
"	43	"	1027	"	86	"	1123
"	44	"	1030	"	87	"	1125
"	45	"	1032	"	88	"	1128
"	46	"	1034	"	89	"	1130
"	47	"	1036	"	90	"	1132
"	48	"	1038	"	91	"	1134
"	49	"	1040	"	92	"	1136
"	50	"	1043	"	93	"	1138
"	51	"	1045	"	94	"	1140
"	52	"	1047	"	95	"	1142
"	53	"	1050	"	96	Blood-heat......	1144
"	54	"	1052	"	97	"	1146
"	55	"	1055	"	98	"	1148
"	56	Temperate.....	1057	"	99	"	1150
"	57	"	1059	"	100	"	1152
"	58	"	1062	"	110	Fever heat 112	1173
"	59	"	1064	"	120	"	1194
"	60	"	1066	"	130	"	1215
"	61	"	1069	"	140	"	1235
"	62	"	1071	"	150	"	1255
"	63	"	1073	"	160	"	1275
"	64	"	1075	"	170	Spirits boil 176	1295
"	65	"	1077	"	180	"	1315
"	66	"	1080	"	190	"	1334
"	67	"	1082	"	200	"	1364
"	68	"	1084	"	210	"	1372
"	69	"	1087	"	212	Water boils	1375
"	70	"	1089	"	302	"	1558
"	71	"	1091	"	392	"	1739
"	72	"	1093	"	482	"	1919
"	73	"	1095	"	572	"	2098
"	74	"	1097	"	680	"	2312

ELASTIC FLUIDS.

Elastic fluids are divided into two classes — permanent gases and vapors. The gases cannot be converted into the liquid state by any known process of art; whereas the vapors are readily reduced to the liquid form by pressure or diminution of temperature. In respect of their mechanical properties there is, however, no essential difference between the two classes. Elastic fluids, in a state of equilibrium, are subject to the action of two forces; namely, gravity, and a molecular force acting from particle to particle. But, in order that all the parts of an elastic fluid may be in equilibrium, one condition only is necessary; namely, that the elastic force be the same at every point situated in the same horizontal plane. This condition is likewise necessary to the equilibrium of liquids, and the same circumstances give rise to it in both cases; namely, the mobility of the particles, and the action of gravity upon them.

The density of bodies being inversely as their volumes, the law of Mariotte may be otherwise expressed by saying the density of an elastic fluid is directly proportional to the pressure it sustains. Under the pressure of a single atmosphere, the density of air is about the 770th part of that of water; whence it follows that, under the pressure of 770 atmospheres, air is as dense as water.

The average atmospheric pressure being thus equal to that of a column of water of about 32 feet in altitude at the bottom of the sea, at the depth of 24,640 (equals 770 multiplied by 32) feet, or $4\frac{2}{3}$ miles, air would be heavier than water; and though it should still remain in a gaseous state, it would be incapable of rising to the surface.

AIR-VESSELS.

The object of an air-vessel on a pump is to cause a better supply of water to the pump, by holding a body of water near to it, and by making the supply of water more uniform and continuous. Consequently, it should be made as long in the neck as would be considered consistent with good proportions, so that the water, in passing through the pump-barrel to the delivery-pipe, could not be forced up into the chamber, as, if such should be the case, the air in the chamber is soon absorbed by the water, and consequently the supply of water is diminished. Great as are the advantages derived from the use of the air-vessels, they often become actually injurious; for, when no advantage is derived from the elasticity of the confined air, the water is impeded in its progress, and as a result its volume is diminished.

Upon the trial of fire-engines, it not unfrequently occurs that they throw the water higher the first few strokes, than when they have been working some time. This is usually attributed to numerous causes, such as obstructions in the pipes, grit or sand under the valves; but, on investigation, it would be more frequently found to be the result of an imperfect air-chamber. The air often makes its escape through minute leaks in the chamber; and when this occurs, the space once occupied by the air becomes filled with the liquid, which not only interferes with the free delivery of the water, but subjects the engine to a very severe strain, which is generally made manifest by heavy laboring and loud knocking in the pump. When long suction-pipes are attached to an engine or pump which is running at a moderate speed, sufficient air is drawn in to supply that taken up by the water; but

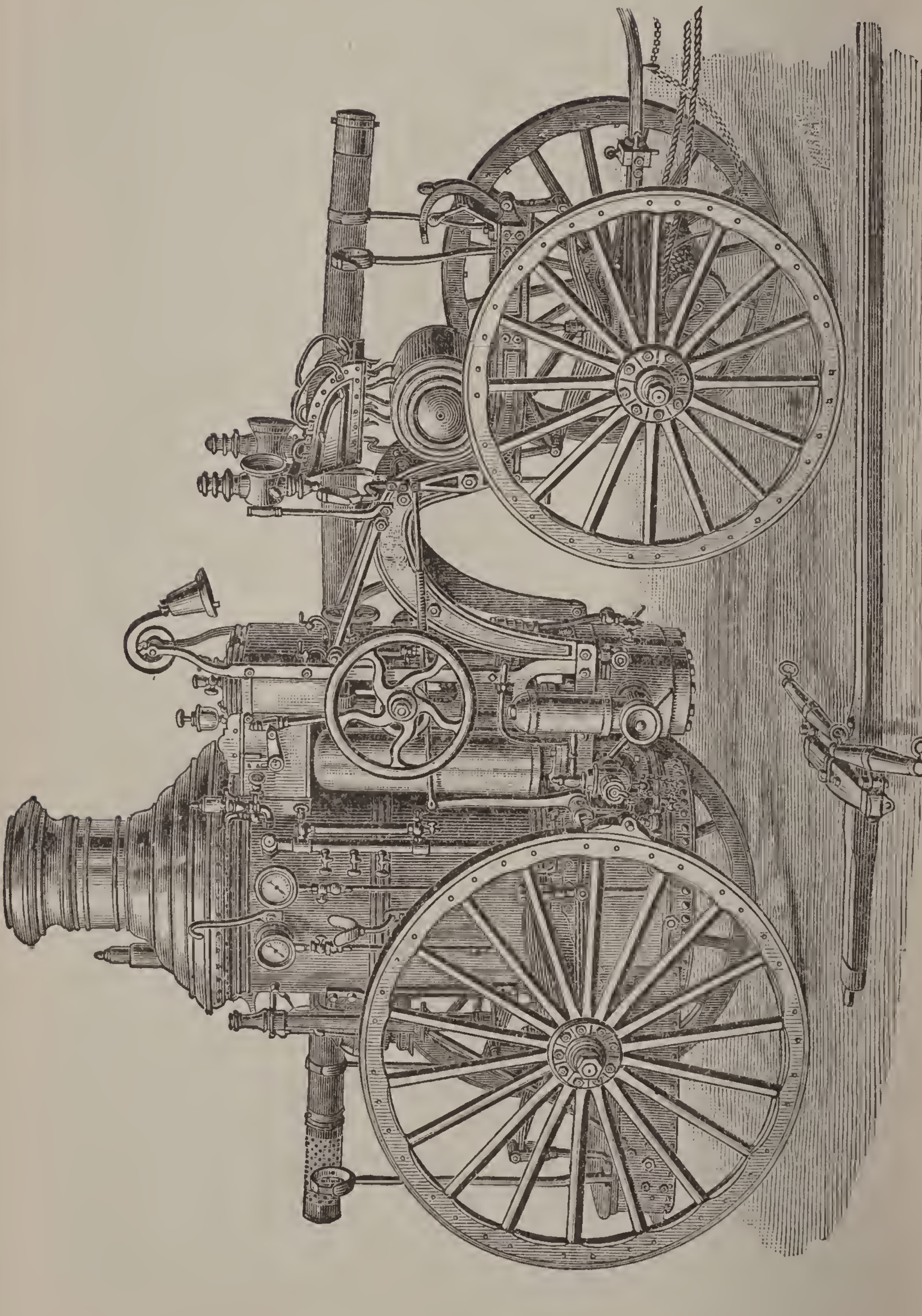
when an engine or pump runs at very high speed, the air in the vessel is liable to be either expelled or condensed.

An air-vessel on a suction-pipe is very beneficial, as it frequently happens in cities that the small head of water in the street mains, and the small pipes used to bring water, prevent a sufficient supply from reaching the pump. The result of this is, that the pump does not do half the work of which it is theoretically capable; for this reason, the addition of an air-chamber below the pump keeps a constant stream flowing to the pump, and at the same time acts as a reservoir, from which the pump may draw a supply at each stroke.

The position of the air-vessel on an engine or pump, and its proportions, form, and the mode of its attachment, will affect the working of the engine or pump in no small degree; the mode in which the water enters and leaves the vessel also influences its usefulness.

In cases where it is manifest that the air-vessel leaks, and it is found impossible to determine the precise location, if some soapsuds be rubbed with the hand on the outside of the vessel, when the engine is working, the bubbles raised by the escaping air will indicate the place where the air escapes.

There does not appear to be any rule by which to determine the capacity of air-vessels for steam fire-engines and fire-pumps; but experience has shown that the air-vessels of steam fire-engines should not have less than twenty times the cubic contents of the water-cylinder. For ordinary steam-pumps, four times the cubic contents of the cylinder will answer. Of course, the larger the air-vessel the easier the pump will work, but the more expensive the air-vessel will be, as, when the diameter of any cylinder is increased, the necessity of increasing the thickness also arises.



THE IMPROVED CLAPP & JONES' STEAM FIRE-ENGINE.

CLAPP AND JONES STEAM FIRE-ENGINE.

The cut on the opposite page represents the Improved Clapp and Jones Steam Fire-Engine. — The boiler is vertical, with fire- and water-tubes. The fire-tubes extend from the crown sheet of the fire-box up through the top of the shell. The water-tubes, the principal feature of this boiler, in form are sectional coils, suspended from the crown, and terminating in the legs after making one turn around the fire-box. There are six of these coils in each circular row. The number of rows being determined by the size of the boiler and the steam required.

Attention is directed to the mode of securing the ends of these water-tubes to the crown and side sheets of the fire-box. This is accomplished by means of unions or couplings, so constructed of different kinds of metal as to preclude the possibility, in their make-up, of two pieces of iron coming in contact to corrode and stick fast, thereby doing away with the danger of destroying any part of either the union or tube forming the sections, so that they could not be replaced again, should it become necessary, from any cause, to remove them from their position.

This boiler possesses the requisites incident to safety in its construction, economy of fuel and quick steam being insured in its design, which affords free circulation of the water in contact with the heated surfaces.

Another good feature, it will not foam or prime during the most excessive firing, consequently no danger of becoming overheated or burned. Either fresh or salt water can be used without inconvenience in generating steam.

The boiler is made of the best material, and in the most substantial and workmanlike manner, and arranged to admit of easy examination, repairs or renewal of any of the parts.

The Engines are either horizontal or vertical, and of that class commonly termed "piston engines," so arranged that the connection between cylinders, steam and water is direct, the pump and steam pistons working simultaneously through rigid connections.

It is claimed for this principle, economy in the use of steam, little friction compared with engines having shafts and gears, or cranks and connecting rods, through which the power of the steam piston is transferred to the pump. Requiring, in consequence of the lack of these things, less fuel, oil and repairs; wear and tear being reduced to a minimum, due to simplicity of construction, there being few wearing surfaces.

The work of friction in this engine is really no greater while working through a long line of hose or when doing the hardest service, than when performing the lightest.

The pump is of novel construction and is made entirely of a composition having high tensile strength, as are also the pins, rods, etc., with no iron parts to rust. The piston is self-packing, requiring no leathers or other artificial means to keep it tight and in working order; it is, therefore, comparatively frictionless, enabling the engine to maintain a high rate of speed and high pressure for very long runs without the danger incident to pumps having their pistons or plungers otherwise constructed.

The pump heads are cages fitted with inlet and outlet valves of simple construction, their elasticity being sufficient to quickly and firmly seat them without the necessity of using the spiral springs, as is generally the practice in pumping machinery. The form of opening in the heads, together with the power and lift of valves, insures ease in the flow of water into and out of the pumps, and precludes the possibility of any of the numerous obstructions which pass the strainer in any manner inter-

fering with the perfect work of the pump. The valves can be removed in five minutes should occasion require, an advantage to be had only in this machine.

A circulating or churn valve controlling a communication between the suction and discharge chambers of this pump is a useful feature, in that the engine may be kept in motion to feed the boiler, should it be necessary to shut off the steam, or for a relief when small nozzles are used, the water passing around through this valve from one chamber of the pump to the other.

All the packed joints are made with a dove-tailed form of groove, to which the packing is fitted, and if not otherwise disturbed the joints may be taken apart and replaced indefinitely without damage to the packing, which will remain in perfect order for years.

The pumps and other portions of this fire-engine are made to gauge, with like parts interchangeable, so that one part of any pump can be applied for like use on another of similar size and style, and also can its other parts be duplicated and so used.

The pump is of such construction that but two pieces are subjected to wear; these can be replaced when necessary at small cost and little trouble, when the pump will be as good for work as when new, no matter how long it may have been in use.

WATER.

Water is in many respects the most important substance known to man; it is more extensively diffused throughout nature than almost any other. It covers the greater part of the earth's surface, and is found to pervade its interior wherever excavations are made. It enters into every, or nearly every, combination of matter, and was supposed by some ancient philosophers to be the origin of all matter, the primordial element of which every object in nature was formed. In the early ages water was reverenced as the substance from which all things in the universe were supposed to be made, and the vivifying principle that animated the whole; hence, rivers, fountains, and wells were worshipped, and religious feasts and ceremonies instituted in honor of them, or of the spirits which were believed to preside over them.

Water being equally as necessary as solid food, man would early be impelled by his appetite to procure it in larger quantities than were required to allay his thirst upon a single occasion, and to devise some means by which he might convey it with him in his wanderings and to his family. It is not improbable that this was the first of man's natural wants which required the exercise of his inventive faculties to supply; as the human family multiplied, its members necessarily kept extending more and more from their first abode, and in searching for suitable locations, the prospect of obtaining water would necessarily exert a controlling influence on their decisions.

Water is the great mechanical power in nature. It is the great leveller — it moves mountains and fills valleys. All our stratified rocks, sandstones, slates, and limestones were formed by the action of water. To the solvent power of water and its chemical actions, we owe our useful min-

erals, our metallic deposits, our iron, zinc, copper, gold, and silver ores, and even coal. To its physical properties we owe all the phenomena of clouds, fog, dew, snow, and frost. It supports the plants, brings them their mineral food from the soil, and protects them from excessive heat.

Water is constantly visible under a variety of conditions. It is seen as ice; in its liquid form it is one of the commonest materials in the world; in the form of steam, it has of late years been most extensively applied in the industrial arts. But water is susceptible of a still further change. It is not a simple substance; it is composed of two others, oxygen and hydrogen; and what seems especially remarkable, the components have themselves never been reduced to material form, either as liquids or as solids, though one of them (hydrogen) has been recently resolved into a metallic base; but the facts obtained in this direction are not sufficiently plain to warrant any definite conclusion.

The Composition of Water.—Pure water is composed of the two gases, hydrogen and oxygen, in the proportions of 2 measures of hydrogen to 1 of oxygen, or, 1 weight of hydrogen to 8 of oxygen; or, oxygen 89 parts by weight, and by measure 1 part, hydrogen, by weight, 11 parts, and by measure 2 parts.

Pure water in nature does not exist, nor is it to be found in the laboratory of the chemist. Fortunately, however, it happens that pure water is not necessary, or even desirable, for household or manufacturing purposes. The presence of air or other gases adds greatly to the ease with which steam may be generated; the ammonia that is present in most water improves it for manufacturing purposes; and it has been abundantly proved that the salts which are present in most well-waters add greatly

to their wholesomeness. But at the same time it must be remembered that some waters contain impurities which render them unfit for use. Of these various impurities, the insoluble portion is in general the least injurious, though it is frequently the most offensive. Water swarming with minute animalcules, or turbid with the clay and sand that have been stirred up from the bed of some stream, may be offensive, though it is not dangerous; while, on the other hand, water may be beautifully clear to the eye and not very offensive to the taste, and yet hold in solution the most deadly poison, in the form of dissolved salts or the soluble portions of animal excreta. It also happens that these insoluble matters are easily and cheaply removed, while the utmost care is required to free water from matter which exists in a dissolved state.

The specific gravity of all waters is not the same. The following table will show the specific gravity of the water of different seas:

	Weight of water being 1000.	Weight of an imperial gallon in pounds.
Water from the Dead Sea	1240	12.4
" " " Mediterranean	1029	10.3
" " " Irish Channel	1028	10.2
" " " Baltic Sea	1015	10.2

For the production of steam, all waters are not equal. Water holding salt in solution, earth, sand or mud in suspension, requires a higher temperature to produce steam of the same elastic force than that generated from pure water.

Water, like all other fluids and gases, expands with heat and contracts with cold down to 40° Fah. If water

be boiled in an open vessel, it is impossible to raise the temperature above 212° Fah., as all the surplus heat which may be applied passes off with the steam. If heat be applied to the top of a vessel, ebullition will not take place, as very little heat would be communicated to other parts of the vessel, and the water would not boil. Ebullition, or boiling of water or other liquids, is effected by the communication of heat through the separation of their particles. The evaporation of water is the conversion of water as a liquid into steam as a vapor.

Latent Heat of Water or Ice.—If a pound of ice at 32° Fah. be mixed with a pound of water at 111°, the water will gradually dissolve the ice, being just sufficient for that purpose, and the residuum will be two pounds of water 32° Fah., showing that the 79 units of heat which were apparently lost had been employed in performing a certain amount of work, viz., in melting the ice or separating the molecules and giving them another shape; and as all work requires a supply of heat to do it, these 79 units have been consumed in performing the work necessary to melt the ice.

Latent Heat of Water.—If the pound of water were reconverted into ice, it would have to give up the 79 units of latent heat. Hence we see why it should be called the latent heat of water, and not the latent heat of ice. Suppose that we have a pound of ice at a temperature of 32° Fah., and that we mix it with a pound of water at 212°, the ice will be melted, and we shall have two pounds of water at a temperature of 51°. Now, if we take a pound of ice at a temperature of 32° and mix it with a pound of water at 212°, the resulting mixture of the two pounds will have a temperature of 122°. Hence we see that the ice, in melting, has absorbed enough heat to raise two pounds of water through a temperature of 122° — 51°

=71°, or one pound through 142°, and we say that the latent heat of the liquefaction of water is 142°.

The latent heat of the evaporation of water can be determined in a similar manner by condensing a pound of steam at 212° Fah. with a given weight of water at a known temperature, and also by mixing a pound of water at a temperature of 212° Fah. with the same amount of water as was employed in the case of steam, and observing the difference of temperature of the resulting mixtures. Thus, a pound of water at 212° mixed with ten pounds at 60° gives eleven pounds at 74°. A pound of steam at 212° mixed with ten pounds of water at 60° gives eleven pounds of water at 162°. In other words, the steam on being condensed has given out heat (which was not previously sensible to the thermometer) enough to raise eleven pounds of water through a temperature of 162° less 74° equals 88°, or one pound through 968°, and we say that the latent heat of the evaporation of water is 968°.

The boiling-point of water is that temperature at which the tension of its vapor balances exactly the pressure of the atmosphere. But the temperature at which the ebullition of water begins depends upon the elasticity of the air or other pressure. At the level of the sea, the barometer standing at 29.905 (or nearly 30) inches of mercury, water will boil at 212° Fah.; but the higher we ascend above the level of the sea, the more the boiling-point diminishes. Although it is claimed that water presses in every direction, and finds its level, yet it can be compressed $\frac{1}{100}$ of an inch in every 18 feet by each atmosphere or pressure of 15 pounds to the square inch of pressure applied; but when the pressure is removed, its elasticity restores it to its original bulk.

Water attains its greatest density at 39° Fah., or 7° above freezing, and becomes solid and crystallized as ice

owing to the abstracting of its heat. The force of expansion exerted by water in the act of freezing has been found irresistible in all mechanical experiments to prevent it, as it expands $\frac{1}{17}$ its original bulk. Water boils in a vacuum at 98° Fah.

Water attains a minimum volume and a maximum density at 40°Fah.; any departure from that temperature in either direction is accompanied by expansion, so that 8° or 10° of cold produce about the same amount of expansion as 8° or 10° of heat. At 70° Fah., pure water will boil at 1° less of temperature, for an average of about 550 feet of elevation above sea-level, up to a height of one-half of a mile. At the height of 1 mile, 1° of boiling temperature will correspond to about 560 feet of elevation.

The following table shows the approximate altitude above sea-level corresponding to different heights, or readings of the barometer; and to the different degrees of Fahrenheit's thermometer, at which water boils in the open air.

TABLE

SHOWING THE BOILING-POINT FOR FRESH WATER AT DIFFERENT ALTITUDES ABOVE SEA-LEVEL.

Boiling-point in deg. Fah.	Altitude above sea-level in feet.	Boiling-point in deg. Fah.	Altitude above sea-level in feet.	Boiling-point in deg. Fah.	Altitude above sea-level in feet.
184°	15221	195°	9031	206°	3115
185°	14649	196°	8481	207°	2589
186°	14075	197°	7932	208°	2063
187°	13498	198°	7381	209°	1539
188°	12934	199°	6843	210°	1025
189°	12367	200°	6304	211°	512
190°	11799	201°	5764	212°	sea-level = 0
191°	11243	202°	5225		
192°	10685	203°	4697		
193°	10127	204°	4169	Below sea-level.	
194°	9579	205°	3642	213°	511

TABLE

SHOWING THE WEIGHT OF WATER.

1	Cubic inch	is equal to	·03617	pounds.
12	Cubic inches	"	·434	"
1	Cubic foot	"	62·5	"
1	Cubic foot	"	7·50	U. S. gallons.
1·8	Cubic foot	"	112·00	pounds.
35·84	Cubic feet	"	2240·00	"
1	Cylindrical inch	"	·02842	"
12	Cylindrical inches	"	·341	"
1	Cylindrical foot	"	49·10	"
1	Cylindrical foot	"	6·00	U. S. gallons.
2·282	Cylindrical feet	"	112·00	pounds.
45·64	Cylindrical feet	"	2240·00	"
11·2	Imperial gallons	"	112·00	"
224·0	Imperial gallons	"	2240·00	"
13·44	U. S. gallons	"	112·00	"
268·8	U. S. gallons	"	2240·00	"

TABLE

SHOWING THE WEIGHT OF WATER AT DIFFERENT TEMPERATURES.

Temperature Fahrenheit.	Weight of a Cubic Foot in Pounds.	Temperature Fahrenheit.	Weight of a Cubic Foot in Pounds.
40°	62.408	172°	60.72
42°	62.406	182°	60.5
52°	62.377	192°	60.28
62°	62.321	202°	60.05
72°	62.25	212°	59.82
82°	62.15	230°	59.37
92°	62.04	250°	58.85
102°	61.92	275°	58.17
112°	61.78	300°	57.42
122°	61.63	350°	55.94
132°	61.47	400°	54.34
142°	61.30	450°	52.70
152°	61.11	500°	51.02
162°	60.92	600°	47.64

TABLE

SHOWING THE WEIGHT OF WATER IN PIPE OF VARIOUS DIAMETERS 1 FOOT IN LENGTH.

Diameter in Inches.	Weight in Pounds.	Diameter in Inches.	Weight in Pounds.	Diameter in Inches.	Weight in Pounds.
1	1/3				
2	1 1/4				
3	3	12 1/4	51	22 1/2	172 1/2
3 1/4	3 1/2	12 1/2	53 1/4	23	180 1/4
3 1/2	4 1/4	12 3/4	55 1/2	23 1/2	188 1/4
3 3/4	4 3/4	13	57 1/2	24	196 1/4
4	5 1/2	13 1/4	59 3/4	24 1/2	204 1/2
4 1/4	6 1/4	13 1/2	62 1/4	25	213
4 1/2	7	13 3/4	64 1/2	25 1/2	222 1/2
4 3/4	7 3/4	14	66 3/4	26	230 1/2
5	8 1/2	14 1/4	69 1/4	26 1/2	239 1/2
5 1/4	9 1/4	14 1/2	71 1/2	27	248 1/2
5 1/2	10 1/2	14 3/4	74 1/4	27 1/2	257 3/4
5 3/4	11 1/4	15	76 3/4	28	267 1/4
6	12 1/4	15 1/4	79 1/4	28 1/2	276 3/4
6 1/4	13 1/4	15 1/2	82	29	286 1/2
6 1/2	14 1/2	15 3/4	84 1/2	29 1/2	296 1/2
6 3/4	15 1/2	16	87 1/4	30	306 3/4
7	16 3/4	16 1/4	90	30 1/2	317 1/4
7 1/4	18	16 1/2	92 1/4	31	327 1/2
7 1/2	19 1/4	16 3/4	95 1/2	31 1/2	338 1/4
7 3/4	20 1/2	17	98 1/2	32	349
8	21 3/4	17 1/4	101 1/2	32 1/2	360
8 1/4	23 1/4	17 1/2	104 1/2	33	371 1/4
8 1/2	24 1/2	17 3/4	107 1/2	33 1/2	382 1/2
8 3/4	26	18	110 1/2	34	394
9	27 1/2	18 1/4	113 1/2	34 1/2	405 3/4
9 1/4	29 1/4	18 1/2	116 1/2	35	417 1/2
9 1/2	30 3/4	18 3/4	119 3/4	35 1/2	429 1/2
9 3/4	32 1/2	19	123	36	441 3/4
10	34	19 1/4	126 1/4	36 1/2	454
10 1/4	35 1/2	19 1/2	129 1/2	37	466 1/2
10 1/2	37 1/2	19 3/4	132	37 1/2	479 1/4
10 3/4	39 1/4	20	136 1/4	38	492 1/4
11	41 1/4	20 1/2	143 1/4	38 1/2	505 1/4
11 1/4	44 1/4	21	150 1/4	39	518 1/2
11 1/2	45	21 1/2	157 1/2	39 1/2	531 3/4
11 3/4	47	22	165	40	545 1/2
12	49				

TABLE

CONTAINING THE DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES, AND THE CONTENTS OF EACH IN GALLONS, AT 1 FOOT IN DEPTH.—UTILITY OF THE TABLE.

EXAMPLES.

1. Required the circumference of a circle, the diameter being five inches?

In the column opposite the given diameter stands 15.708* inches, the circumference required.

2. Required the capacity in gallons of a can, the diameter being 6 feet and depth 10 feet?

In the fourth column from the given diameter stands 211.4472,* being the contents of a can 6 feet in diameter and 1 foot in depth, which being multiplied by 10 gives the required contents, 2114½ gallons.

3. Any of the areas in feet multiplied by .03704, the product equals the number of cubic yards at 1 foot in depth.

4. The area of a circle in inches multiplied by the length or thickness in inches, and by .263, the product equals the weight in pounds of cast-iron.

* For decimal equivalents to the fractional parts of a gallon or an inch, see table on page 219.

TABLE

OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES, AND THE CONTENTS IN GALLONS AT 1 FOOT IN DEPTH.

DIAM.	CIR.	AREA.	GALLONS.	DIAM.	CIR.	AREA.	GALLONS.
Inch.	Inch.	Inch.		Inch.	Inch.	Inch.	
1	3.1416	.7854	.04084	1/8	19.242	29.464	1.53213
1/8	3.5343	.9940	.05169	1/4	19.635	30.679	1.59531
1/4	3.9270	1.2271	.06380	3/8	20.027	31.919	1.65979
3/8	4.3197	1.4848	.07717	1/2	20.420	33.183	1.72552
1/2	4.7124	1.7671	.09188	5/8	20.813	34.471	1.79249
5/8	5.1051	2.0739	.10784	3/4	21.205	35.784	1.86077
3/4	5.4978	2.4052	.12506	7/8	21.598	37.122	1.93034
7/8	5.8905	2.7611	.14357	7	21.991	38.484	2.00117
2	6.2832	3.1416	.16333	1/8	22.383	39.871	2.07329
1/8	6.6759	3.5465	.18439	1/4	22.776	41.282	2.14666
1/4	7.0686	3.9760	.20675	3/8	23.169	42.718	2.22134
3/8	7.4613	4.4302	.23036	1/2	23.562	44.178	2.29726
1/2	7.8540	4.9087	.25522	5/8	23.954	45.663	2.37448
5/8	8.2467	5.4119	.28142	3/4	24.347	47.173	2.45299
3/4	8.6394	5.9395	.30883	7/8	24.740	48.707	2.53276
7/8	9.0321	6.4918	.33753	8	25.132	50.265	2.61378
3	9.4248	7.0686	.36754	1/8	25.515	51.848	2.69609
1/8	9.8175	7.6699	.39879	1/4	25.918	53.456	2.77971
1/4	10.210	8.2957	.43134	3/8	26.310	55.088	2.86458
3/8	10.602	8.9462	.46519	1/2	26.703	56.745	2.95074
1/2	10.995	9.6211	.50029	5/8	27.096	58.426	3.03815
5/8	11.388	10.320	.53664	3/4	27.489	60.132	3.12686
3/4	11.781	11.044	.57429	7/8	27.881	61.862	3.21682
7/8	12.173	11.793	.61324	9	28.274	63.617	3.30808
4	12.566	12.566	.65343	1/8	28.667	65.396	3.40059
1/8	12.959	13.364	.69493	1/4	29.059	67.200	3.49440
1/4	13.351	14.186	.73767	3/8	29.452	69.029	3.58951
3/8	13.744	15.033	.78172	1/2	29.845	70.882	3.68586
1/2	14.137	15.904	.82701	5/8	30.237	72.759	3.78347
5/8	14.529	16.800	.87360	3/4	30.630	74.662	3.88242
3/4	14.922	17.720	.92144	7/8	31.023	76.588	3.98258
7/8	15.315	18.665	.97058	10	31.416	78.540	4.08408
5	15.708	19.635	1.02102	1/8	31.808	80.515	4.18678
1/8	16.100	20.629	1.07271	1/4	32.201	82.516	4.29083
1/4	16.493	21.647	1.12564	3/8	32.594	84.540	4.39608
3/8	16.886	22.690	1.17988	1/2	32.986	86.590	4.50268
1/2	17.278	23.758	1.23542	5/8	33.379	88.664	4.61053
5/8	17.671	24.850	1.29220	3/4	33.772	90.762	4.71962
3/4	18.064	25.967	1.35028	7/8	34.164	92.885	4.82846
7/8	18.457	27.108	1.40962	11	34.557	95.033	4.94172
6	18.849	28.274	1.47025	1/8	34.950	97.205	5.05466

TABLE—(*Continued*)

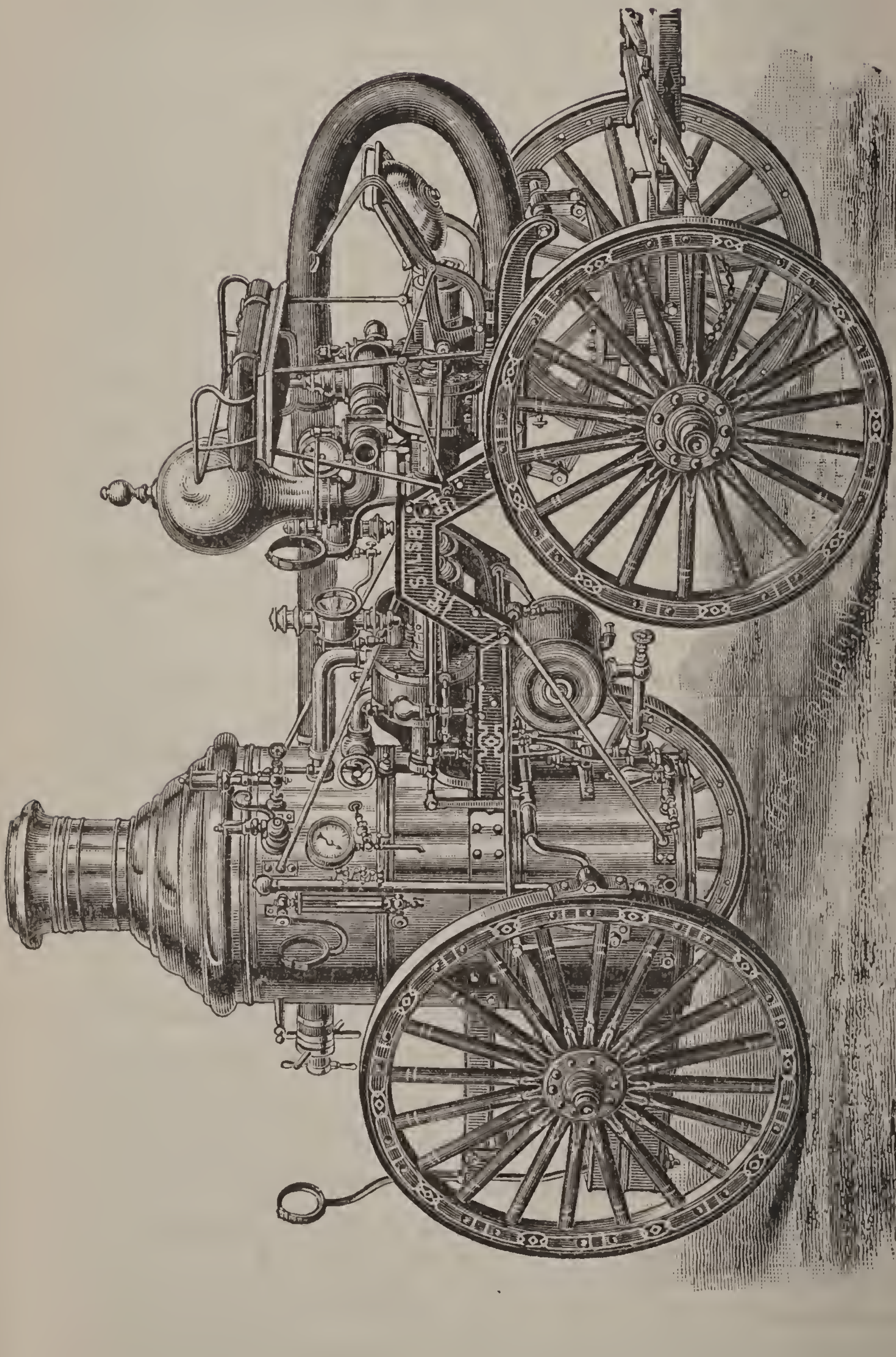
OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES, AND THE CONTENTS IN GALLONS AT 1 FOOT IN DEPTH.

DIAM.	CIR.	AREA.	GALLONS.	DIAM.	CIR.	AREA.	GALLONS.
Inch.	Inch.	Inch.		Inch.	Inch.	Inch.	
$\frac{1}{4}$	35.343	99.402	5.16890	3 10	12 $5\frac{1}{2}$	11.5409	86.3074
$\frac{3}{8}$	35.735	101.623	5.28439	3 11	12	12.0481	90.1004
$\frac{1}{2}$	36.128	103.869	5.40119	4	12 $6\frac{3}{4}$	12.5664	93.9754
$\frac{5}{8}$	36.521	106.139	5.51923	4 1	12 $9\frac{7}{8}$	13.0952	97.9310
$\frac{3}{4}$	36.913	108.434	5.63857	4 2	13 1	13.6353	101.9701
$\frac{7}{8}$.	37.306	110.753	5.75916	4 3	13 $4\frac{1}{8}$	14.1862	103.0300
				4 4	13 $7\frac{1}{4}$	14.7479	110.2907
Ft. In.	Ft. In.	Feet.		4 5	13 $10\frac{1}{2}$	15.3206	114.5735
1	3 $1\frac{5}{8}$	.7854	5.8735	4 6	14 $1\frac{5}{8}$	15.9043	118.9386
1 1	3 $4\frac{5}{8}$	.9217	6.8928	4 7	14 $4\frac{5}{8}$	16.4986	123.3830
1 2	3 8	1.0690	7.9944	4 8	14 $7\frac{7}{8}$	17.1041	127.9112
1 3	3 11	1.2271	9.1766	4 9	14 11	17.7205	132.5209
1 4	4 $2\frac{1}{8}$	1.3962	10.4413	4 10	15 $2\frac{1}{8}$	18.3476	137.2105
1 5	4 $5\frac{3}{8}$	1.5761	11.7866	4 11	15 $5\frac{1}{4}$	18.9858	142.0582
1 6	4 $8\frac{1}{2}$	1.7671	13.2150	5	15 $8\frac{1}{2}$	19.6350	146.8384
1 7	4 $11\frac{5}{8}$	1.9689	14.7241	5 1	15 $11\frac{5}{8}$	20.2947	151.7718
1 8	5 $2\frac{3}{4}$	2.1816	16.3148	5 2	16 $2\frac{3}{4}$	20.9656	156.7891
1 9	5 $5\frac{7}{8}$	2.4052	17.9870	5 3	16 $5\frac{3}{4}$	21.6475	161.8886
1 10	5 9	2.6398	19.7414	5 4	16 9	22.3400	167.0674
1 11	6 $2\frac{1}{4}$	2.8852	21.4830	5 5	17 $0\frac{1}{8}$	23.0437	172.3300
2	6 $3\frac{3}{8}$	3.1416	23.4940	5 6	17 $3\frac{1}{4}$	23.7583	177.6740
2 1	6 $6\frac{1}{2}$	3.4087	25.4916	5 7	17 $6\frac{3}{8}$	24.4835	183.0973
2 2	6 $9\frac{5}{8}$	3.6869	27.5720	5 8	17 $9\frac{5}{8}$	25.2199	188.6045
2 3	7 $0\frac{3}{4}$	3.9760	29.7340	5 9	18 $0\frac{3}{4}$	25.9672	194.1930
2 4	7 $3\frac{7}{8}$	4.2760	32.6976	5 10	18 $3\frac{7}{8}$	26.7251	199.8610
2 5	7 7	4.5869	34.3027	5 11	18 $7\frac{1}{8}$	27.4943	205.6133
2 6	7 $10\frac{1}{4}$	4.9087	36.7092	6	18 $10\frac{1}{8}$	28.2744	211.4472
2 7	8 $1\frac{3}{8}$	5.2413	39.1964	6 3	19 $7\frac{1}{2}$	30.6796	229.4342
2 8	8 $4\frac{1}{2}$	5.5850	41.7668	6 6	20 $4\frac{7}{8}$	33.1831	248.1564
2 9	8 $7\frac{5}{8}$	5.9395	44.4179	6 9	21 $2\frac{3}{8}$	35.7847	267.6122
2 10	8 $10\frac{3}{4}$	6.3049	47.1505	7	21 $11\frac{7}{8}$	38.4846	287.8032
2 11	9 $1\frac{7}{8}$	6.6813	49.9654	7 3	22 $9\frac{1}{4}$	41.2825	308.7270
3	9 5	7.0686	52.8618	7 6	23 $6\frac{3}{4}$	44.1787	330.3859
3 1	9 $8\frac{1}{4}$	7.4666	55.8382	7 9	24 $4\frac{1}{8}$	47.1730	352.7665
3 2	9 $11\frac{3}{8}$	7.8757	58.8976	8	25 $1\frac{1}{2}$	50.2656	375.9062
3 3	10 $2\frac{1}{2}$	8.2957	62.0386	8 3	25 11	53.4562	399.7668
3 4	10 $5\frac{5}{8}$	8.7265	65.2602	8 6	26 $8\frac{3}{8}$	56.7451	424.3625
3 5	10 $8\frac{3}{4}$	9.1683	68.5193	8 9	27 $5\frac{3}{4}$	60.1321	449.2118
3 6	10 $11\frac{7}{8}$	9.6211	73.1504	9	28 $3\frac{1}{4}$	63.6174	475.7563
3 7	11 3	10.0846	75.4166	9 3	29 $0\frac{5}{8}$	67.2007	502.5536
3 8	11 $6\frac{1}{8}$	10.5591	78.9652	9 6	29 $10\frac{1}{8}$	70.8823	530.0861
3 9	11 $9\frac{3}{8}$	11.0446	82.5959	9 9	30 $7\frac{1}{2}$	74.6620	558.3522

TABLE—(*Concluded*)

OF DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES, AND THE CONTENTS IN GALLONS AT 1 FOOT IN DEPTH.

Diam.		Cir.		Area.	Gallons.	Diam.		Cir.		Area.	Gallons.
Ft.	In.	Ft.	In.	Feet.		Ft.	In.	Ft.	In.	Feet.	
10		31	5	78.5400	587.3534	20	6	64	$4\frac{3}{4}$	330.0643	2468.3528
10	3	32	$2\frac{3}{8}$	82.5160	617.0876	20	9	65	$2\frac{1}{4}$	338.1637	2528.9233
10	6	32	$11\frac{3}{4}$	86.5903	647.5568	21		65	$11\frac{5}{8}$	346.3614	2590.2290
10	9	33	$9\frac{1}{4}$	90.7627	678.2797	21	3	66	9	354.6571	2652.2532
11		34	$6\frac{5}{8}$	95.0334	710.6977	21	6	67	$6\frac{1}{2}$	363.0511	2715.0413
11	3	35	$4\frac{1}{8}$	99.4021	743.3686	21	9	68	$3\frac{7}{8}$	371.5432	2778.5486
11	6	36	$1\frac{1}{2}$	103.8691	776.7746	22		69	$1\frac{3}{8}$	380.1336	2842.7910
11	9	36	$10\frac{7}{8}$	108.4342	810.9143	22	3	69	$10\frac{3}{4}$	388.8220	2907.7664
12		37	$8\frac{3}{8}$	113.0976	848.1890	22	6	70	$8\frac{1}{4}$	397.6087	2973.4889
12	3	38	$5\frac{3}{4}$	117.8590	881.3966	22	9	71	$5\frac{5}{8}$	406.4935	3039.9209
12	6	39	$3\frac{1}{4}$	122.7187	917.7395	23		72	3	415.4766	3107.1001
12	9	40	$0\frac{5}{8}$	127.6765	954.8159	23	3	73	$0\frac{1}{2}$	424.5577	3175.0122
13		40	10	132.7326	992.6274	23	6	73	$9\frac{7}{8}$	433.7371	3243.6595
13	3	41	$7\frac{1}{2}$	137.8867	1031.1719	23	9	74	$7\frac{1}{4}$	443.0146	3313.0403
13	6	42	$4\frac{7}{8}$	143.1391	1070.4514	24		75	$4\frac{3}{4}$	452.3904	3383.1563
13	9	43	$2\frac{1}{4}$	148.4896	1108.0645	24	3	76	$2\frac{1}{8}$	461.8642	3454.0051
14		43	$11\frac{3}{4}$	153.9384	1151.2129	24	6	76	$11\frac{5}{8}$	471.4363	3525.5929
14	3	44	$9\frac{1}{8}$	159.4852	1192.6940	24	9	77	9	481.1065	3597.9068
14	6	45	$6\frac{5}{8}$	165.1303	1234.9104	25		78	$6\frac{3}{8}$	490.8750	3670.9596
14	9	46	4	170.8735	1277.8615	25	3	79	$3\frac{7}{8}$	500.7415	3744.7452
15		47	$1\frac{1}{2}$	176.7150	1321.5454	25	6	80	$1\frac{1}{4}$	510.7063	3819.2657
15	3	47	$10\frac{7}{8}$	182.6545	1365.9634	25	9	80	$10\frac{3}{4}$	520.7692	3894.5203
15	6	48	$8\frac{1}{4}$	188.6923	1407.5165	26		81	$8\frac{1}{8}$	530.9304	3970.5098
15	9	49	$5\frac{3}{4}$	194.8282	1457.0032	26	3	82	$5\frac{1}{4}$	541.1896	4047.2322
16		50	$3\frac{1}{8}$	201.0624	1503.6250	26	6	83	3	551.5471	4124.6898
16	3	51	$0\frac{1}{2}$	207.3946	1550.9797	26	9	84	$0\frac{3}{8}$	562.0027	4202.9610
16	6	51	10	213.8251	1599.0696	27		84	$9\frac{7}{8}$	572.5566	4281.8072
16	9	52	$7\frac{3}{8}$	220.3537	1647.8930	27	3	85	$8\frac{1}{8}$	583.2085	4361.4664
17		53	$4\frac{7}{8}$	226.9806	1697.4516	27	6	86	$4\frac{5}{8}$	593.9587	4441.8607
17	3	54	$2\frac{1}{8}$	233.7055	1747.7431	27	9	87	$2\frac{1}{8}$	604.8070	4522.9886
17	6	54	$11\frac{5}{8}$	240.5287	1798.7698	28		87	$11\frac{1}{2}$	615.7536	4604.8517
17	9	55	$9\frac{1}{8}$	247.4500	1850.5301	28	3	88	9	626.7982	4686.4876
18		56	$6\frac{1}{2}$	254.4696	1903.0254	28	6	89	$6\frac{3}{8}$	637.9411	4770.7787
18	3	57	4	261.5872	1956.2537	28	9	90	$3\frac{3}{4}$	649.1821	4854.8434
18	6	58	$1\frac{3}{8}$	268.8031	2010.2171	29		91	$1\frac{1}{4}$	660.5214	4939.6432
18	9	58	$10\frac{3}{4}$	276.1171	2064.9140	29	3	91	$10\frac{5}{8}$	671.9587	5025.1759
19		59	$8\frac{1}{4}$	283.5294	2120.3462	29	6	92	$8\frac{1}{8}$	683.4943	5111.4487
19	3	60	$5\frac{5}{8}$	291.0397	2176.5113	29	9	93	$5\frac{1}{2}$	695.1280	5198.4451
19	6	61	$3\frac{1}{8}$	298.6483	2233.2914	30		94	$2\frac{7}{8}$	706.8600	5286.1818
19	9	62	$0\frac{1}{2}$	306.3550	2291.0452	30	3	95	$0\frac{3}{8}$	718.6900	5374.6512
20		62	$9\frac{7}{8}$	314.1600	2349.4141	30	6	95	$9\frac{3}{4}$	730.6183	5463.8558
20	3	63	$\frac{3}{8}$	322.0630	2408.5159	30	9	96	$7\frac{1}{4}$	742.6447	5553.7940



THE MODERN SILSBY ROTARY CRANE-NECK STEAM FIRE-ENGINE.

SILSBY ROTARY STEAM FIRE-ENGINE.

The cut on the opposite page illustrates the Silsby Rotary Steam Fire-Engine.

The boiler (see cut), is vertical and cylindrical; from the crown sheet depend water-tubes having in them concentric circulation tubes, causing in each tube a strong central downward current of water, which, mostly converted into steam, ascends in a thin film in the annular space between the outer and inner tubes. These drop-tubes are arranged in concentric circles, those in the outside rows being longer than the others, thus properly utilizing the space in the combustion chamber. The gases of combustion pass from the furnace through vertical smoke flues set concentrically, a conical smoke chamber connecting with the stack, and the draught is regulated by a variable exhaust nozzle. This nozzle has several outlets, making the blast steady and reliable.

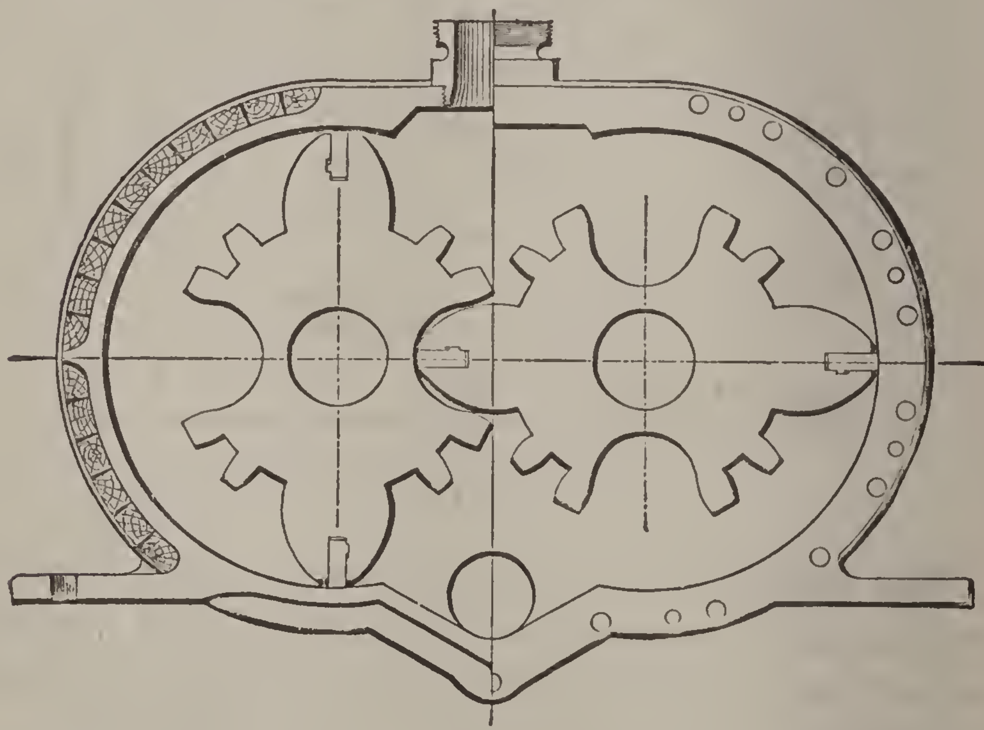
The water-tubes are screwed into the crown sheet, and the circulation tubes have at their lower ends triangular casements to prevent the lifting of the water by the rapid circulation.

The steam made in the drop-tubes and elsewhere is dried and further heated by the smoke flues, and is then taken from a circular perforated dry pipe running around the steam space of the boiler.

The water-tubes may be unscrewed and replaced in a few minutes, and all the smoke flues can be readily got at by removing the dome. This style of boiler possesses many advantages for steam fire-engine use. It has great steaming capacity combined with compactness and durability, and that prerequisite quality, quick steaming. It is made of homogeneous "mild" steel. All joints are permanently tight. All heating surfaces, being straight, are easily cleaned, and all those exposed to the direct

action of the fire are covered with water. It will burn coal or wood, will not prime and can use salt water. The circulation being so rapid there is no chance for the accumulation of mud or scales.

By a special arrangement by which a portion of the exhaust steam is utilized for heating to boiling point the water in the feed tank, this boiler is fed with hot instead of cold water, thus effecting a great saving of fuel, and relieving the boiler of the evil results from unequal contraction and expansion with a cold feed.

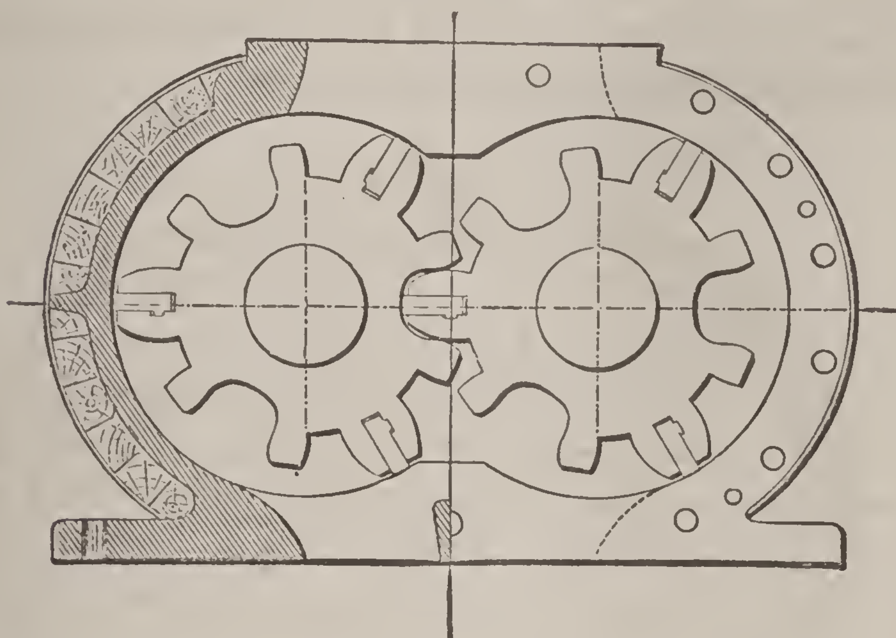


The engine (see cut), contains two rotating cams, both alike, each of which has eight short teeth and one long tooth, with one deep space between each two pairs of short teeth. The long teeth are abutments for the steam, forming steam-tight joints with the walls of the case in which they rotate and with the deep spaces in which they engage.

The tightness of the joints is insured by packing-pieces set out by springs, and controlled by suitable feathers.

The heads of the cams are turned to fit the case, and are provided with recesses for lubricants.

The steam entering at the bottom of the case presses the abutments apart, and thus causes the cams to rotate in opposite directions. The journals revolve in a special patented form of bearing preventing overheating and any leakage of steam.



The pump (see cut), is constructed upon the same general principle as the engine, only there are three long teeth to each cam and fewer short teeth. The water enters at the bottom of the case at the suction opening, and it is discharged at the outlet on top. The revolution of the pump cams in opposite directions causes a vacuum in the case, the water then rushes up to fill it and is caught by the long teeth and swept out of the case. There are no valves in this pump. It is coupled directly on to the shaft of the engine, revolving simultaneously with it, and its rotation is further insured by well-cut gears upon the shafts outside of the steam and water cases. The journals of both engine and pump run in long bearings, and there are suitable stuffing boxes to insure steam and water-tight

joints for the shaft. The packing-pieces in the ends of the long teeth, on which is the only wear, can be removed through openings in the side of the case, there being no necessity for taking either the engine or pump apart. The stuffing-boxes reduce friction, insure absolute tightness, so that there is no leakage of either steam or water, and there is no necessity for frequent repacking.

The rotary engine and pump undoubtedly embody the true principle for forcing water, and hence they are peculiarly adapted for steam fire-engine use. They are light, compact, and the parts are simple and few in number. The action between the two being rotary and direct there is no jar to the machine incidental to the use of the crank, consequently there is no external wear on the hose. The absence of valves allows the use of any kind of water for fire purposes without danger of clogging the pump, insuring absolute reliability, a prerequisite in a fire-engine.

The Silsby Engine combines all the essential points of a good machine, such as strength, durability and efficiency. They are built of the best materials, and fitted in a most thorough manner, all the parts being made to gauge and in duplicate. They are finished in the highest style, all the exposed metal parts being heavily nickel-plated. Each machine is furnished with a full complement of supplies. The modern Silsby steam fire-engine embraces all the improvements made in that class of machinery during the last thirty years, they having been built by the present manufacturers, The Silsby Manufacturing Co., of Seneca Falls, New York, since 1856.

DISCHARGE OF WATER THROUGH APERTURES.

In circular apertures in a thin plate on the bottom or side of a reservoir, the issuing stream tends to converge to a point distant about one-half its diameter from outside

of the orifice, reducing the quantity nearly $\frac{3}{8}$ths from the quantity due to the velocity corresponding to the height. When water issues from a short tube, the flow is less contracted than in the former case, viz., in the ratio of 16 to 13.

With a conical aperture whose greater base is the aperture, the height of the frustum being half the diameter of the aperture, and the area of the small end to the area of the large end as 10 to 16, there will be no contraction of the vein. Hence this form gives the greatest flow.

The quantity of water flowing from a vertical, rectangular aperture reaching to the surface, is two-thirds of the quantity that would flow out of the same aperture placed horizontally at the depth of the base.

The quantity of water discharged during the same time by the same orifices under different heads, are nearly as the square roots of the corresponding heights of the water in the reservoir above the surface of the orifices.

Small orifices, on account of friction, discharge proportionally less fluid than those which are larger and of the same figure, under the same pressure.

Circular apertures are the most efficacious, having less rubbing surface under the same area.

If the cylindrical, horizontal tube through which water is discharged, be of greater length than the diameter, the discharge is much increased; it can be increased to advantage to four times the diameter of the orifice.

To find the velocity of the flow of water through canals, etc. Multiply the head or fall in feet by the area of the cross-section of the stream in square feet, and divide the product by the length of the channel in feet; the square root of the quotient multiplied by 774.6, equals the velocity in feet per minute.

TABLE

SHOWING THE THEORETICAL DISCHARGE OF WATER BY ROUND APERTURES OF VARIOUS DIAMETERS, AND UNDER DIFFERENT HEADS OF WATER PRESSURE.

Diameter in Inches.	Head of Water in Inches.																
	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24
	Discharge in Gallons per Minute.																
1	4.7	6.6	8.1	9.4	10.5	11.5	12.4	13.3	14.1	14.8	16.2	17.6	18.8	19.9	21	22	23
2	18.8	29.4	34.2	37.6	42 0	46.0	49.6	53.2	56.4	59.2	64.8	70.4	75.2	79.6	84	88	92
3	42.2	56.4	72.9	84.6	94.5	103	112	120	127	133	146	158	169	179	189	198	207
4	75.2	106	130	150	168	184	198	213	225	237	259	281	301	318	336	352	368
5	117	165	203	235	282	287	310	332	352	370	405	440	470	497	525	550	575
6	169	237	291	338	378	414	446	479	507	533	583	663	677	716	756	792	828
7	230	310	397	460	514	563	607	652	691	725	794	862	921	975	1029	1078	1127
8	301	422	518	601	672	736	793	851	902	947	1037	1126	1203	1273	1344	1408	1472
9	381	534	656	761	850	931	1006	1077	1142	1199	1312	1425	1523	1612	1701	1782	1863
10	470	660	810	940	1050	1150	1240	1330	1411	1480	1620	1760	1880	1990	2100	2200	2300
12	676	952	1168	1353	1512	1656	1785	1915	2030	2134	2333	2534	2707	2865	3024	3170	3312
14	920	1241	1588	1842	2058	2254	2430	2606	2764	2901	3175	3450	3684	3900	4116	4312	4508
16	1203	1690	2074	2406	2688	2944	3174	3405	3610	3789	4147	4506	4813	5094	5376	5632	5888
18	1523	2138	2624	3045	3402	3726	4018	4309	4568	4795	5249	5702	6091	6447	6804	7128	7452
20	1880	2640	3240	3760	4200	4600	4960	5320	5640	5920	6480	7040	7520	7960	8400	8800	9200
22	2275	3194	3920	4550	5082	5566	6002	6437	6824	7163	7841	8518	9099	9632	10164	10648	11132
24	2704	3808	4672	5414	6048	6624	7140	7660	8120	8536	9332	10136	10829	11460	12096	12680	13248
30	4230	5940	7290	8460	9450	10350	11160	11970	12690	13320	14580	15840	16920	17910	18900	19800	20700
Velocity in ft. per second	2.32	3.275	4.01	4.63	5.18	5.67	6.13	6.55	6.95	7.32	8.03	8.67	9.27	9.83	10.36	10.87	11.35

TABLE

SHOWING THE ACTUAL DISCHARGE BY SHORT TUBES OF VARIOUS DIAMETERS, WITH SQUARE EDGES AND UNDER DIFFERENT HEADS OF WATER PRESSURE, BEING $\frac{8}{10}$THS OF THE THEORETICAL DISCHARGE.

Dia in In.	Head of Water in Inches.																
	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24
	Discharge in Gallons per Minute.																
1	3.76	5.28	6.48	7.52	8.4	9.2	9.9	10.6	11.3	11.8	13.0	14.1	15 0	15.9	16.8	17.6	18.4
2	15.04	21.12	25.9	30.1	33.6	36.8	39.7	42.6	45.1	47.4	51.8	56.3	60.2	63.7	67.2	70·4	73.6
3	33.8	47.5	58.3	67.7	75.6	82.4	89.6	96.0	101.6	106 4	116.8	126	135	143	151	158	166
4	60.2	84.8	104	120	130	147	158	170	180	189	207	225	241	254	269	282	294
5	93.6	132	162	188	210	230	248	266	282	296	324	352	376	398	420	440	460
6	135	190	233	270	302	331	357	382	406	426	466	530	542	573	605	634	662
7	194	248	318	368	411	450	486	522	553	580	636	689	737	780	823	862	902
8	241	338	414	481	538	589	634	681	722	758	829	901	962	1018	1075	1126	1178
9	305	427	525	609	680	745	805	863	910	959	1049	1140	1218	1290	1361	1426	1490
10	376	528	648	752	840	920	992	1064	1129	1184	1296	1408	1504	1592	1680	1760	1840
12	541	762	934	1082	1210	1325	1428	1532	1624	1707	1866	2027	2166	2292	2419	2536	2650
14	736	993	1268	1474	1646	1803	1944	2085	2211	2321	2540	2760	2947	3120	3293	3450	3606
15	846	1188	1458	1692	1890	2070	2232	2394	2288	2664	2916	3168	3384	3582	3780	3960	4140
16	962	1352	1659	1925	2150	2355	2539	2724	2888	3031	3318	3605	3850	4075	4301	4406	4710
18	1218	1710	2099	2436	2722	2981	3214	3447	3662	3836	4199	4562	4873	5158	5443	5702	5962
20	1504	2112	2592	3008	3360	3680	3968	4256	4512	4736	5184	5632	6016	6368	6720	7040	7360
22	1820	2552	3136	3640	4065	4452	4801	5149	5459	5730	6272	6814	7279	7705	8131	8518	8905
24	2163	3046	3737	4331	4838	5299	5712	6128	6496	6828	7465	8108	8663	9168	9676	10144	10598
30	3384	4752	5832	6768	7560	8280	8928	9576	10152	19656	11664	12672	13536	14328	15120	15840	16560

TABLE

SHOWING THE DISCHARGE OF JETS WITH DIFFERENT HEADS.

Head on Jet in Feet.	Diameter of Jet in Inches.																
	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$
	Gallons Discharged per Minute.																
5	.537	1.21	2.15	3.36	4.83	6.58	8.59	13.4	19.3	26.3	34.4	53.7	77.0	105	137	174	215
10	.758	1.71	3.03	4.74	6.82	9.30	12.1	18.9	27.3	37.1	48.5	75.8	109	148	194	244	303
15	.929	2.09	3.72	5.81	8.36	11.4	14.8	23.2	33.4	45.5	59.4	92.9	134	182	238	301	372
20	1.07	2.41	4.29	6.70	9.66	13.0	17.2	26.8	38.6	52.6	68.6	107	154	210	274	347	429
25	1.20	2.70	4.80	7.50	10.8	14.7	19.2	30.0	43.2	58.8	76.8	120	173	235	307	389	480
30	1.31	2.95	5.25	8.21	11.8	16.1	21.0	32.8	47.3	64.4	84.1	131	189	258	336	426	525
35	1.42	3.19	5.68	8.87	12.8	17.4	22.7	35.5	51.1	69.6	90.9	142	204	278	364	460	568
40	1.52	3.41	6.07	9.48	13.6	18.6	24.7	37.9	54.6	74.3	97.1	152	218	297	388	491	609
45	1.61	3.62	6.44	10.1	14.5	20.2	25.8	40.3	58.0	80.7	103	161	232	323	412	522	644
50	1.70	3.82	6.79	10.6	15.2	21.3	27.1	42.4	61.1	84.9	109	170	244	340	434	550	680
60	1.86	4.18	7.44	11.6	16.7	22.8	29.7	46.4	66.9	91.1	119	186	267	364	476	602	744
70	2.01	4.52	8.03	12.5	18.1	24.5	32.1	50.1	72.3	98.4	129	201	289	393	514	650	803
80	2.14	4.83	8.58	13.4	19.3	26.3	34.3	53.6	77.2	105	137	215	309	421	549	695	858
90	2.27	5.12	9.10	14.2	20.5	27.9	36.4	56.9	82.0	111	145	227	328	446	593	738	910
100	2.40	5.40	9.6	15.0	21.6	29.4	38.4	60.0	86.4	117	153	240	346	471	615	778	960
110	2.52	5.66	10.1	15.7	22.6	30.9	40.3	62.9	90.6	123	161	252	362	493	644	815	1010
120	2.63	5.91	10.5	16.4	23.6	32.6	42.0	65.7	94.6	130	168	263	378	522	673	852	1052
130	2.73	6.15	10.9	17.1	24.6	33.5	43.7	68.4	98.5	134	175	273	394	536	700	886	1094
140	2.84	6.39	11.3	17.7	25.5	34.8	45.4	71.0	102	139	181	284	409	557	727	920	1136
150	2.94	6.61	11.7	18.4	26.4	36.0	47.0	73.5	106	144	188	294	423	576	752	952	1176
175	3.17	7.14	12.7	19.8	28.5	39.0	50.8	79.4	114	156	203	317	457	621	813	1029	1270
200	3.39	7.63	13.5	21.2	30.5	41.5	54.3	84.8	122	166	217	339	490	665	869	1099	1358
250	3.79	8.53	15.1	23.7	34.1	46.5	60.7	94.8	136	186	243	379	546	744	971	1230	1518
300	4.15	9.35	16.6	25.9	37.4	50.1	66.5	104	149	201	266	415	598	816	1061	1346	1663

TABLE

SHOWING THE NUMBER OF GALLONS OF WATER DISCHARGED THROUGH DIFFERENT SIZE APERTURES, AND WITH DIFFERENT HEADS, IN ONE MINUTE AND IN TWENTY-FOUR HOURS.

DIAM. OF APER.		3·16		1·4		3·8		1·2	
Head of Water in Feet.	Pounds Pressure per Sq. In.	GALLONS DISCHARGED.		GALLONS DISCHARGED.		GALLONS DISCHARGED.		GALLONS DISCHARGED.	
		Per Minute.	Per 24 Hrs.	Per Minute.	Per 24 Hrs.	Per Minute.	Per 24 Hrs.	Per Minute.	Per 24 Hrs.
20.	8.8	3.29	4737	5.76	8294	13.16	18948	23.04	33176
40.	17.6	4.64	6681	8.32	11884	18.56	26724	33.28	47536
60.	26.4	5.69	8193	10.24	14560	22.76	32772	40.96	58240
80.	35.2	6.58	9475	11.52	16588	26.32	37900	46.08	66352
100.	44.	7.36	10598	12.8	18432	29.44	42392	51.2	73728
120.	52.8	8.06	11606	14.08	20256	32.24	46424	56.32	81024
140.	61.6	8.7	12528	15.36	22118	32.28	50112	61.44	88472
160.	70.4	9.3	13392	16.48	23808	37.2	53568	65.92	95232
180.	79.2	9.87	14212	17.28	24880	39.48	56848	69.12	99520
200.	88.	1.04	14976	18.56	26724	41.6	59904	74.24	106896
		5·8		3·4		7·8		1	
20.	8.8	36.5	52646	52.6	75792	71.6	103204	92.1	132704
40.	17.6	51.6	74347	74.2	106896	101.2	145728	133.1	190144
60.	26.4	63.3	91166	91.	131088	124.1	178718	163.8	232960
80.	35.2	73.1	105307	105.2	151600	143.3	206424	184.3	265408
100.	44.	81.8	117777	117.7	169568	160.3	230846	204.8	294912
120.	52.8	89.5	128995	128.9	185696	175.5	252835	225.2	324096
140.	61.6	96.7	139291	129.1	200448	189.6	273009	245.7	353888
160.	70.4	103.3	148752	148.8	214272	202.6	291744	263.6	380928
180.	79.2	109.7	157968	157.9	227392	215.	309600	276.4	398080
200.	88.	115.6	166464	166.4	239616	226.6	326304	296.8	427584

TABLE—(*Continued.*)

DIAM. OF APER.		1 1·8		1 1·4		1 3·8		1 1·2	
Head of Water in Feet.	Pounds Pressure per Sq. In.	GALLONS DISCHARGED. Per Minute.	GALLONS DISCHARGED. Per 24 Hrs.	GALLONS DISCHARGED. Per Minute.	GALLONS DISCHARGED. Per 24 Hrs.	GALLONS DISCHARGED. Per Minute.	GALLONS DISCHARGED. Per 24 Hrs.	GALLONS DISCHARGED. Per Minute.	GALLONS DISCHARGED. Per 24 Hrs.
20.	8.8	118.4	170496	146.	210584	176.9	254736	210.	303168
40.	17.6	168.2	242208	206.4	297388	249.8	359712	296.8	427584
60.	26.4	205.1	295344	253.2	364664	306.4	441216	364.	524352
80.	35.2	236.9	341136	292.4	421228	353.9	509616	420.	606400
100.	44.	265.	381600	327.2	471108	395.8	569952	470.8	678272
120.	52.8	290.2	417888	358.	515980	433.5	624240	515.6	742784
140.	61.6	313.4	451296	386.8	557164	468.1	674064	516.4	801792
160.	70.4	334.9	482256	413.2	595008	500.3	720432	595.2	857088
180.	79.2	355.4	511776	438.8	631872	530.4	763776	631.	909568
200.	88.	374.7	539568	462.4	665856	559.7	805968	665 6	958464
		1 3·4		2		2 1·4		2 1·2	
20.	8.8	286.	412816	368.	530816	473.	681984	584.	842336
40.	17.6	404.	582912	532.	760576	672.	968832	825.	1189552
60.	26.4	496.	714872	655.	931840	840.	1181376	1012.	1258656
80.	35.2	573.	825696	737.	1061632	947.	1364544	1169.	1684912
100.	44.	641.	923384	819.2	1179648	1060.	1526400	1308.	1884432
120.	52.8	702.	1011340	900.	1296384	1160.	1671552	1432.	2063920
140.	61.6	758.	1092036	982.	1415552	1253.	1805184	1547.	2228656
160.	70.4	810.	1166976	1054.	1523712	1339.	1929024	1652.	2380032
180.	79.2	860.	1238400	1105.	1592320	1421.	2047104	1755.	2527488
200.	88.	906.	1305216	1187.	1710336	1498.	2158272	1849.	2663424

RULES.

Rule *for finding the Time a Cistern will take in filling, when a known Quantity of Water is going in and a known Quantity is going out, in a given time.*— Divide the contents of the cistern, in gallons, by the difference of the quantity going in and the quantity going out, and the quotient is the time in hours and parts that the cistern will take in filling.

Rule *for finding the Time a Vessel will take in Emptying itself of Water.*— Multiply the square root of the depth in feet by the area of the falling surface in inches; divide the product by the area of the orifice, multiply by 3.7, and the quotient is the time required in seconds, nearly.

Rule *for finding the Quantity of Water discharged through an Orifice per Minute.*— Multiply the area of the orifice in square feet by the square root of the height of the level of the water above the orifice in feet, and the product multiplied by 297.6 will be equal to the discharge in cubic feet, nearly.

Rule *for finding the Quantity of Water a Steam-boiler or any Cylindrical Vessel will contain.*— Multiply the area of the head or base in inches by the length in inches, and divide the product by 1728; the quotient will be the number of cubic feet of water the boiler or vessel will contain. If the boiler contains flues or tubes, their combined area in inches by their length in inches must be deducted from the above product.

Rule *for finding the Requisite Quantity of Water for a Steam-boiler.*—When the number of pounds of coal consumed per hour can be ascertained, divide it by 7.5, and the quotient will be the required quantity of water in cubic feet per hour.

Rule *for finding the Required Height of a Column of*

Water to supply a Steam-boiler against any given Pressure of Steam.— Multiply the boiler pressure in pounds per square inch by 2.5; the product will be the required height in feet above the surface of the water in the boiler.

Rule *for finding the Diameter of a Pipe sufficient to Discharge a given Quantity of Water per Minute in Cubic Feet.*— Multiply the square of the quantity in cubic feet per minute by .96, and the product equals the diameter of the pipe in inches.

Rule *for finding the Number of U. S. Gallons contained in a Foot of Pipe of any given Diameter.*— Square the diameter of the pipe in inches, multiply the square by .0408; the product is U. S. gallons.

Rule *for finding the Power required to raise Water to any Height.*— Multiply the perpendicular height of the water, in feet, by the velocity also in feet, and by the square of the pump's diameter in inches, and again by .341; divide this product by 33,000, and one-fifth of the quotient added to the whole quotient will be the number of horse-power required.

Rule *for finding the Pressure in Pounds per Square Inch exerted by a Column of Water.*— Multiply the height of the column in feet by 0.434, and the product will be the pressure in pounds per square inch.

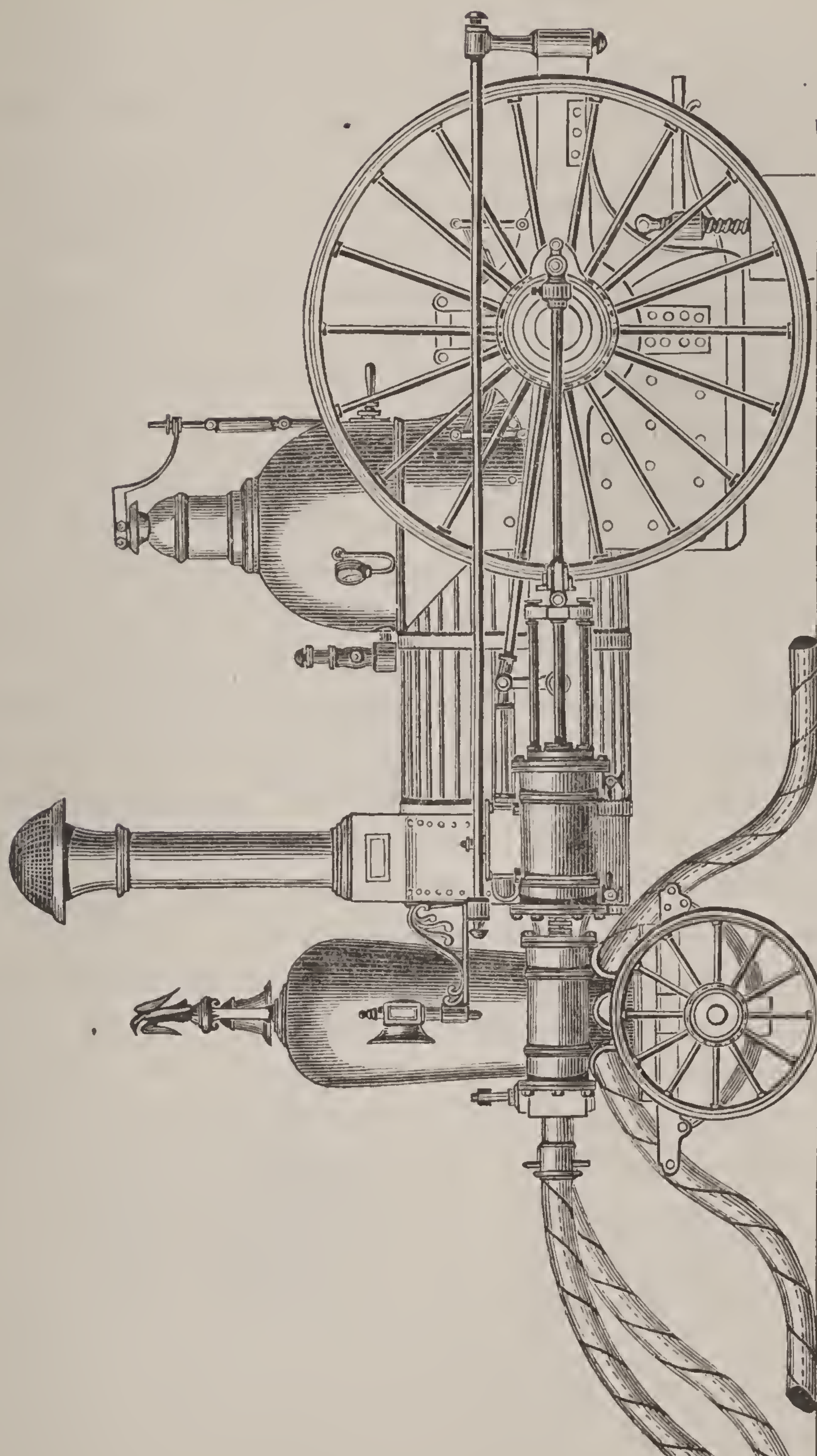
Rule *for finding the Head of Water in Feet, Pressure being known.*— Multiply the pressure per square inch by 2.314. The pressure per square foot equals the height of the column in feet multiplied by 62.4.

Water is the grand agent that nature has provided for the extinguishment of fires, and contrivances for applying it with effect have, in every civilized country, been assiduously sought for. In the absence of more suitable implements, buckets, and other portable vessels of capacity at hand, have always been seized to convey and throw water on fires; and when used with celerity and presence of mind, at the commencement of one, have often been sufficient; but when a conflagration extends beyond their reach, the fate of the burning building is sealed, unless some more efficient means of extinguishing the fire is at hand. Consequently, the necessity of some device by which a stream of water could be forced from a distance on flames, must have been early perceived; and if we were to judge from the frequency and extent of ancient conflagrations, the prodigious amount of property destroyed, and of human misery superinduced by them, we should conclude that ingenious men of former times were stimulated in an unusual degree to invent machines for the purpose.

That this was the case, cannot well be questioned, although no account of their labors has reached our times; yet it seems more than probable that the celebrated cities of remote antiquity had their fire-engines, as it is not at all likely that the mechanics of such cities as Nineveh and Babylon would have left their splendid edifices destitute of the means of protection from the ravages of the fire-fiend. But fire-engines were nearly or altogether forgotten in the middle ages, portable syringes being the only contrivances — except buckets — for throwing water on fires; and from their inefficiency, and other causes, their employment was very limited. The general ignorance which then pervaded Europe not only prevented the establishment of manufactories for better instruments, but the superstitions of the times actually discouraged their use.

But when the useful arts began to excite attention, the defects of portable syringes were too apparent to be neglected. Hence, in the early part of the sixteenth century, several attempts were made to remedy them by those noble spirits who burst through the prejudice that had so long consigned the subjects of practical mechanics to the mere makers of machines, as one unworthy of a philosopher's pursuit, and from the cultivation of which no distinction, save such as was allied to that of an artisan, could be derived. The important results of their labors to mankind, however, gave a dignity to skilful mechanics, notwithstanding the degraded state in which operatives had been held in those times by those who had lived on their ingenuity, and become enriched by their skill.

For a long time there was no definite size of fire-engines, and in fact no regular system, either as to their manufacture or use. At length, however, two of the most important improvements ever made in the fire-engine were introduced about the same time, namely, the air-chamber and flexible hose, which add immensely to the efficiency of the modern fire-engine. By the former, the stream ejected from a single pump was rendered continuous; and by the latter, it was no longer necessary to take the engine itself close to a building on fire. The manual fire-engines have received but little attention for several years past, and have undergone but very slight improvements; and, as they are destined to be entirely superseded by the steam fire-engine, it is unnecessary to devote much space here to an explanation of their mechanism or working principles.



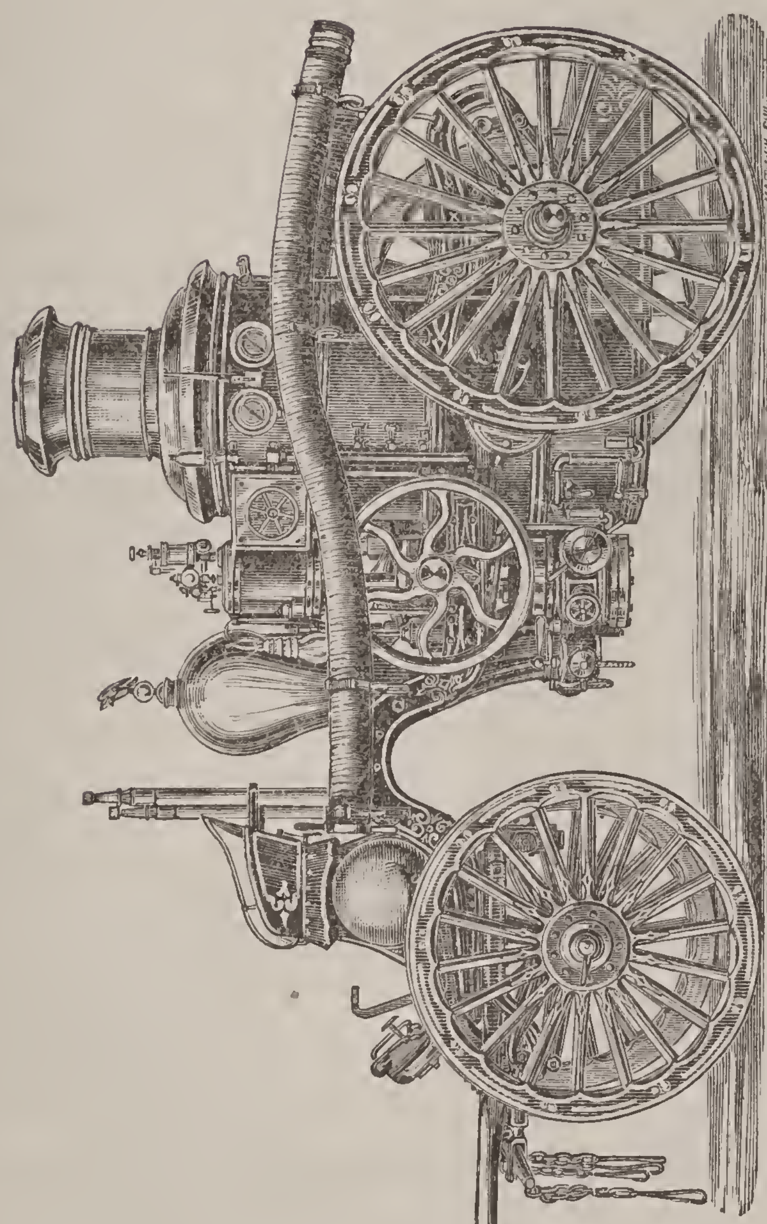
HODGE'S STEAM FIRE-ENGINE.—1840.

STEAM FIRE-ENGINES.

The first steam fire-engine built in this country was constructed in 1840, by P. R. Hodge, an ingenious mechanical engineer of New York, a cut of which may be seen on page 86. The engines were horizontal, and had their cylinders attached to the smoke-box of a tubular-boiler of the locomotive type, with steam-dome. The pistons of the steam- and water-cylinders were on the same rods; and the connecting-rods were attached to cranks on the hind wheels, which served as balance-wheels when the engine was blocked up for service. The pumps had receiving-screws on the sides, and delivery-screws on the ends. The engine was self-propelling, and very efficient; but such was the prejudice of the volunteer fire department against the introduction of such a means of extinguishing fires, that it was allowed to fall into disuse, and it required twelve years to fully convince property owners, underwriters, and insurance companies that it was necessary to provide some more efficient means of extinguishing fires than the manual engines. The weight of this celebrated engine was about 3000 pounds.

The next successful steam fire-engine in this country—in fact, in the world — was the "Joe Ross," built in 1852, by A. B. Latta, for the city of Cincinnati; and, although on trial it proved to be superior to any other known device for extinguishing fires, there was a great deal of prejudice and opposition offered to its employment for that purpose.

Since then the growth and improvement of the steam fire-engine has been steady and progressive, and at the present time the manufacture of these engines is among the most important and prosperous mechanical industries of the country. The number of steam fire-engines in use



THE AMOSKEAG IMPROVED STEAM FIRE-ENGINE.

in the United States at the close of 1875 was 1400. Some of the finest mechanical talent in the country has for several years past been devoted to the improvement of the steam fire-engine, and as a result, the American Steam Fire-Engine, in symmetry of parts, elegance of finish, and efficiency of action, stands unrivalled by any other in the world. The writer, to satisfy himself on this subject, made an examination of a great variety of steam fire-engines, both of this country and Europe, and he found many of the European fire-engines very defective in design, complicated in parts, and inefficient in action; while, on the other hand, the American engines in general were found simple in design, perfect in proportion, elegant in finish, and efficient in action. They were, also, as a general thing, in better order and more efficiently managed.

NAMES OF THE PRINCIPAL MANUFACTURERS OF MODERN FIRE-ENGINES.

Silsby Mfg. Co., Seneca Falls, N. Y.
Ahrens Mfg. Co., Cincinnati, Ohio.
Clapp & Jones, Hudson, N. Y.
Manchester Loco. Co., Manchester, N. H.
Button Fire-Engine Co., Waterford, N. Y.
W. H. Lang, Goodhue & Co., Burlington, Vt.
The La France Fire-Engine Co., Elmira, N. Y.
Holloway Chemical Fire-Engine, Baltimore, Md.

AMOSKEAG STEAM FIRE-ENGINE.

The engraving illustrates the modern Amoskeag Steam Fire-Engine, manufactured by the Manchester Locomotive Works, Manchester, N. H. These engines are vertical, with steam cylinder and pumps attached to an upright tubular boiler, with submerged smoke-box. The pumps are double-acting, with receiving-

screws on each side, and are surrounded by a circular chamber, which forms the suction and discharge openings. The pumps have separate valve-plates at the top and bottom, which form the seats of the suction and discharge valves; each of these plates can easily be reached by removing the top or bottom of the pump, which makes it very convenient for cleaning or repairs when it becomes necessary. The discharge and suction chambers of these pumps are connected by a relief-valve.

The Amoskeag engines are built either single or double, self-propelling or to be drawn by horses, with either straight or crane-neck frames. There is very little difference in the general appearance or weight between the self-propelling engines and those intended to be drawn by horses. They are mounted upon patent platform springs in such a manner that the springs bear the weight, but sustain no part of the draft strain. The propelling is done by the same engines that are used for the pumps, and being reversible, they can be propelled either backwards or forwards as desired. The propelling is effected by an endless chain working over sprocket-wheels on the driving-shafts and rear-axles. The propelling gear is very simple in its construction, and so arranged as not to interfere in the least with the use of the ordinary drawing rig for either men or horses, should it under any circumstances become necessary to use them. The steering apparatus is also so arranged as to require very little exertion on the part of the driver to keep the machine in line, or to change the inclination of the wheels even when traveling at a high speed. They can be turned with great ease, and within very narrow limits, by means of a set of compound gearing so arranged on the axle that in turning the engine the two rear wheels are driven at varying speeds.

The Amoskeag engines embody some very fine mechanical conceptions in their design and construction; they are

probably the most powerful and efficient engines in the country, and are perhaps in more general use than any other. They are made of the best material, and all the parts most likely to wear or suffer by accident are made to standard gauges, and duplicated; consequently, they can be renewed at short notice. The boilers and steam-cylinders are covered with either ornamental wood or Russian iron, and banded with brass, nickel plate, or German silver. Each engine is furnished with the following supplies: 20 feet of suction hose, a suitable brass strainer for suction hose, a brass hydrant connection for suction hose, a brass signal-whistle, two plated gauges — one steam and one water; two discharge pipes for leading hose, with a complete set of changeable nozzles from $\frac{7}{8}$ inch diameter to $1\frac{1}{4}$, two brass-bound firemen's hand lanterns, a large brass oil can, a jack-screw for convenience in oiling the axles, a coal shovel and fire poker; a tool box containing all the tools necessary to be used in the running or adjustment of the engine and pumps.

EARLY FORMS OF STEAM FIRE-ENGINES.

In the early days of the steam fire-engine, brass, copper, and wrought iron were the materials most generally employed in their construction, the quantity of either used varying according to the fancy of the builder; but steel now seems to possess extra advantages for the construction of different parts of such machines, as, by its use, they can be made sufficiently strong with very moderate weight and bulk, which is a consideration of great importance. Metallic valves were also at one time in almost universal use, but they are being very rapidly replaced by flexible materials. Many of the engines now in use in this country have conical India-rubber disk-valves, held in position by

spiral springs, which answer a very good purpose, as they give sufficient area of opening with very limited lift. Crane-neck frames are also fast taking the place of the straight or parallel, as they admit of the boiler and machinery being placed lower down on the frame, and afford great facilities for turning round in narrow streets or contracted situations.

The blower-pipe, that was at one time so extensively used in the smoke-stacks of fire-engines for the purpose of increasing the draught, is now nearly, if not entirely, superseded by the variable-exhaust, and nearly, if not all, fire-engine houses have stationary steam-boilers, generally located in the cellar, on which steam is kept up steadily for the purpose of keeping the water in the boiler of the steam fire-engine hot; this arrangement obviates the necessity of burning gas-jets in the furnace, as was generally the custom some years ago. Nearly any of the present class of improved steam fire-engines can raise steam in from 10 to 12 minutes while running to a fire.

The pumps of steam fire-engines, both of this country and Europe, are of different kinds, each one of which is claimed to possess some advantages over the others; but with them, as with all kinds of machines, it will be found that the simplest are generally the most durable and efficient. Their cylinders have also been placed in different positions, vertical, horizontal, incline, etc.; but the vertical seems to be superseding all others at the present time, as fire-engines with their cylinders in this position are enabled to use vertical pumps, and can be attached directly to the boiler, which makes the working of the engine more steady in consequence of the weight being against the lift; moreover, they are as a general thing more compact and strong than the horizontal engines, and avoid the loss incurred by carrying steam from the boiler to the cylinder

through pipes exposed to the atmosphere. The wear on the rubbing surfaces of vertical engines is also less than horizontal or inclined engines suffer.

The water-pistons of steam fire-engines, like those of steam-pumps, are almost exclusively made of leather, as that material possesses superior advantages over any other for that purpose; they are either made solid or in the shape of a disk. To make the disk-packing, the best description of leather is taken, and cut in circles about two inches larger in diameter than the pump-cylinder, after which they are soaked in lukewarm water for several hours; they are then placed on a rod, and screwed up between two flanges, and by means of a nut and screw drawn into a cylinder of about the same diameter as that of the pump, and allowed to dry; after which they can be removed and hung up for future use.

In some instances, the piston-packing is formed by placing several flanges of leather on the piston-rod, and screwing them up, after which the rod is placed in a lathe, and the flanges turned to suit the diameter of the pump-cylinder. This method of packing, though very good, is not so tight as the disk, as the pressure adjusts the latter to the form of the cylinder. When making a solid leather piston, it is not necessary to soak the leather.

The difficulty which so materially interfered with the usefulness of the steam fire-engine for many years after its introduction, that of being manufactured at a great distance from the locations at which they were intended to be used, and having, in case of accident, repairs, or alterations, to be transported to the place where they were originally built, is now successfully overcome by the establishment of machine-shops in connection with nearly all the fire departments in this country.

The application of the relief-valve for the purpose of regulating the pressure in the air-vessel, and preventing the discharge-hose from bursting, like the air-vessel, the flexible-hose, and the reducing-screw, by which to connect the suction-hose with the ordinary fire-plug, added very much to the efficiency and economy of the steam fire-engine.

Many of the steam fire-engines that were in general use a few years ago, have gradually disappeared. This resulted from the fact, that in all large cities under the volunteer system, there were more steam fire-engines than were required. Under the Paid Fire Department system all the worn out, complicated, or inefficient engines were allowed to fall into disuse, or were sold to country towns, and none retained but those that had a good reputation for efficiency, durability, and economy.

The most essential requisites of the steam fire-engine are: *simplicity of design, fewness of parts, strength, durability, lightness, and efficiency.* These are all very important points, and should be carefully attended to, as the neglect of any one of them may, in a measure, defeat the object to be attained in the use of the machine.

On the design of an engine, whether fire, stationary, locomotive, or marine, rests its success, as a badly made engine can be rebuilt, but an inferior design will render every attempt to increase its efficiency a failure. The strains induced by the movement of engines of all classes may be called the base upon which their designs should be decided. Movements determine the general dimensions, and strains should decide the proportions of different parts; movements and strains together must, therefore, be considered in deciding the proper area of service exposed to wear. Therefore, in designing any machine, symmetry should be observed, in order that all the working points may be accessible without derangement, and at the same

time, the strain or wear on each part in directing the movements of the machine must be duly considered.

It is desirable that the parts of a fire-engine should be as few as possible, and be readily accessible for adjustment or repairs, as it must be borne in mind, that the fewer the parts in any machine, and the simpler the construction, the more satisfactory will be the results.

Complicated machines, however well constructed, are always difficult and expensive to repair, as a great loss of time is frequently incurred in handling, repairing, or re-adjusting such a multiplicity of parts. They also require more intelligent, and consequently more expensive, attendants, when, if simple in design and properly constructed, they can be managed by persons having only a slight knowledge of machinery, which is a feature of great importance, particularly in places where there happens to be a scarcity of skilled engineers or machinists. The true secret of success in the employment of any class of machines is, to construct them on a principle that will insure the greatest possible amount of work with the least expenditure.

Strength is a very important feature in a steam fire-engine, but it should be attained rather by the quality and disposition made of the metal employed than by weight, as all the material used over and above that which would give sufficient strength, if well proportioned, not only acts as a dead weight, but detracts very much from the advantages of the machine. Steel and the higher grades of wrought iron, particularly the former, possess very high qualities for the construction of different parts of the steam fire-engine, as, when well proportioned for the position it is to occupy, the parts may be made light, and at the same time possess great strength, advantages which show themselves whenever an engine is subjected to severe treatment.

From the very nature of the work that a steam fire-engine has to perform, it is very desirable that it should possess the quality of durability in a very eminent degree, as it would be somewhat difficult to decide whether the strains to which it is subjected when in action, or the jarring it receives in going to or coming from fires, is the more detrimental to its durability. Consequently, in the proportioning of the different parts of the machine, these two contingencies should be amply provided for; all the bearings for the revolving or vibrating parts should be of sufficient dimensions to prevent the possibility of rapid wear, the rubbing surfaces of ample area, the piston and valve-rods should be made of steel, and the pump-cylinders of metal composed of nine parts of brass to one of tin, but no zinc. The springs should be sufficiently strong to prevent the possibility of breaking, and at the same time possess the required elasticity to relieve the machine from the excessive jarring to which it is exposed when travelling over rough surfaces.

Lightness, as far as is consistent with strength and safety, is also very desirable in the steam fire-engine; but as the circumstances under which they are used are so varying, no rule can be given that would apply to the proportioning of all the different parts; consequently, experience and judgment have to be the guides in such cases, and the different parts have to be designed with a view to durability and to safety rather than to show and extreme lightness. One of the best aids for the attainment of lightness in all machines is the use of a superior quality of metal in their construction.

Efficiency of Steam Fire-Engines.—To determine the relative efficiency of steam fire-engines, viewing them simply as hydraulic machines, it is necessary to note, 1st, the extreme vertical height and horizontal distance to which

the water can be thrown; 2d, the volume or quantity delivered in a certain time to that height and distance; 3d, the total power given out by the engine and consumed in performing that work in the unit of time. In short, the engine that possesses the power of raising steam most rapidly, maintaining it steadily; which is simple, durable, strong and light, and which is able to throw water with the greatest force and energy, the earliest after arriving at a fire, is the most efficient engine.

The distance and height to which a jet of water can be thrown by a steam fire-engine are influenced by many conditions: the diameter of the jet, the diameter of the hose, the smoothness of its interior, the mode of coupling, the position of the hose on the ground, the freedom from sharp bends, etc. All these affect the range most seriously; but the greatest drawback is that of the atmosphere, which increases as the square of the velocity. For this reason, an engine at high pressure does not give results proportionate to those attained through the same nozzle at a much lower pressure. The power of an engine may be diminished in other ways,—such as by drawing the water from a source far below the pump; by forcing it into the air-vessel in cases where the latter leaks; by hose badly constructed, and with couplings contracting the water-ways, instead of which, they ought to be of the same size as the internal diameter of the hose. These are some of the causes of diminishing the power that would otherwise be expended in projecting the column of water to its full height or length.

There are other sources of loss in the pumps of steam fire-engines, such as the contraction of the fluid-vein entering the suction-pipe, and in its passage through the pump to the hose. The meeting of two separate currents by the delivery of two alternate streams into a common

passage; the friction in the tubes and passages; the small and peculiar construction of the valves in some cases; the disproportion in the sectional area of the barrel and that of the suction- and force-pipes, constitute three other sources of loss. The form of the suction-pipe at which the water enters, and of the force-pipe at the end where the water is discharged; the form of both of these pipes where they unite with the barrel; the proportional length of the barrel to the depth from which the water is raised, may also be added to the list of sources of loss. All these combined, consume the power that would otherwise be exerted in raising and discharging the column of water, so that in many instances not more than 50 per cent. of the work due to the power of the engine is utilized in the pump.

Experiments both in this country and Europe have shown that, as a general thing, fire-engines, when at work under the most favorable circumstances, do not perform more than from one-half to two-thirds the theoretic duty due to the pressure in the pump-cylinder; and the higher the pressure at which such engines are worked, the more apparent this discrepancy becomes, and instead of obtaining, with a pressure of 120 lbs on the square inch, a vertical height of 270′, which is about the theoretic height due to that pressure, it will be found that it does not exceed 140′, unless everything is under the most favorable conditions. Again, to double the distance or height within certain limits, the pressure requires to be three times as great. The loss of power induced by forcing water through long lengths of leather hose has been variously estimated; and experiments have shown that pumping engines with a long stroke, and making but very few in a given time, and allowing a short pause at the end of each stroke for the water to fill the passages, and insure a solid body of water for the power to work against, gave the most satisfactory results.

The wear and tear of the working parts are also greatly diminished by such an arrangement.

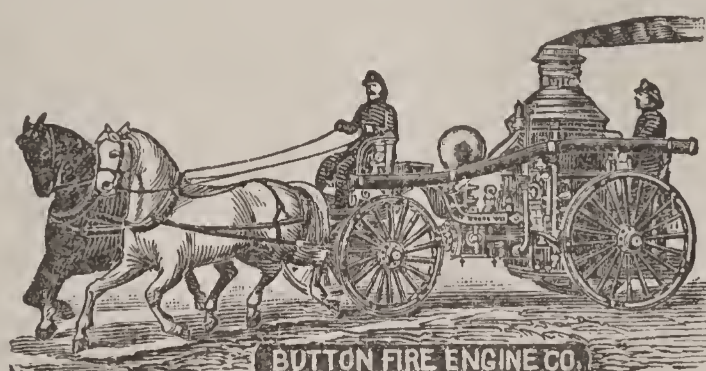
Steam fire-engines may be divided into two classes — slow- and fast-running engines; and both of these classes have their respective advocates; but it has been found in practice that short-stroke engines are to be preferred in all respects, as the engine making the greatest number of strokes does, as a general thing, the greatest amount of duty. But it must be remembered that the wear on fast-running engines is greater than on those that run slowly, as the moving parts have to change their direction more frequently. They are also more liable to break down. Nevertheless, steam fire-engines should be so designed as to be capable of working at either slow or fast speed, and to discharge an amount of water proportionate to the speed at which they are worked.

FLOATING STEAM FIRE-ENGINES.

The use of floating steam fire-engines seems to be receiving encouragement in all large commercial cities, where property of immense value is often collected on the banks of rivers or wharves, and where, in consequence of an unlimited supply of water, such engines are capable of rendering most efficient service. The great extent of water-front, and the long line of shipping which bound nearly all the great commercial cities of this country, and the dangers to which they are exposed from fire, render the introduction and successful employment of floating steam fire-engines an object of great importance. The floating steam fire-engine in New York harbor is said to have rendered very efficient service. The pumps are 11 $\times$ 12, and were built by the Manchester Locomotive Company.

THE BUTTON STEAM FIRE-ENGINE.

The cut represents the Button Steam Fire-Engine, the boilers of which are a modification of the upright tubular, in which is introduced a very efficient circulating device. They are the only upright tubular boilers which can properly be called circulating boilers. The flues are of copper and are secured in heavy tube sheets at each end, and protected from injury by the outside shell of the boiler. They are always covered with water at whatever inclination the engine can be worked.



The advantages claimed for these boilers are that the flues being of copper never corrode, that they are better conductors of heat than iron, that owing to the arrangement of the materials they are not strained or made to leak by the expansion or contraction induced by varying temperatures, that they are easily kept clean and otherwise cared for, and that the circulation of the water over the heated surfaces is complete and rapid.

These engines are built with crane-neck running gear without reach and can be turned around in a space as wide as they are long.

The pumps are double and what is known as "duplex." They have neither cranks, balance wheels, connecting rods nor eccentrics. There are no revolving parts, but the piston of one engine controls the valve of the other reciprocally. They are capable of being run

at very high velocities without jar or concussion, and will throw a quantity of water proportionate to their speed, working steadily and quietly whether running one hundred strokes a minute or six hundred. The pumps are of the best bronze metal and are so arranged that the water cannot come in contact with the iron, thus removing any possibility of rust, however long they may be out of use. The water-ways are direct and large, which insures a full supply of water to the pumps, with very little loss by friction, even at very high velocities. The pumps are in one casting with no bolted or packed partitions.

The pumps and steam cylinders are so constructed as to be entirely independent, for their strength, of the framework or boiler. They are suspended from the framework, but form no part of it nor of the bracing, consequently no unevenness of ground, nor unequal strain upon the running gear, nor any expansion by heat, can throw them out of line.

The Button Steam Fire-Engine, both in its boiler and its working parts, combines simplicity, efficiency, convenience and economy in a very marked degree.

The Button Fire-Engines, hand and steam, have been manufactured for more than half a century under the supervision of the veteran fire-engine builder, Mr. L. Button.

The steam fire-engines are manufactured in six sizes and are all furnished with the usual supplies and attachments.

TRIALS OF STEAM FIRE-ENGINES.

As the legitimate use of a steam fire-engine is to put out fires, the main object to be determined at the trial of steam fire-engines is to ascertain the quantity of water each engine can project through the air, and to what height and distance. Now, there are many conditions which assist or interfere with the efficiency of an engine, all of which should be carefully noted as follows:

The time required to raise steam from the moment the smoke appears at the top of the chimney.

The height of the water in the boiler.

The rapidity with which the engine can be brought into action.

If the engine moves smoothly when started.

If steam was maintained at the same pressure during the whole duration of the trial.

The pressure indicated by the gauges on the boiler and pumps.

If the vibration of the engine when working is severe.

The size of the nozzle.

The distance the engine has to lift the water.

The diameter and length of the suction-holes.

The diameter of the steam- and water-cylinders.

The number of revolutions.

The cubic feet of water in each boiler at the time the fire was lighted. This is a necessary precaution, as some boilers contain a larger amount of water than others to the square foot of heating surface, consequently, the boiler containing the least quantity of water would steam the fastest.

Whether the streams are solid or broken, steady or intermittent.

The distance at which the jet begins to scatter.

The resistance of the wind at the time of making the test; and if great accuracy be desired, it would be necessary to protect the stream as much as possible from the wind.

Every fire-engine before it is accepted should be thoroughly tested in the manner in which it will be used at fires, and the test continued for three or four hours at a time.

In order to test the power and condition of a steam fire-engine, let the boiler-pressure be about 60 lbs. to the square inch; close the pump outlets while the engine is pumping water, and let the throttle-valve remain wide open, when, if the engine is in perfect order, the pressure will rise rapidly on the water-gauge, and it will stop working after a few strokes. But if the engine continues to move, and stops only on the centres, and the pressure on the water-gauge does not rise, it is evident that there is a leak somewhere; it may be in the piston, or pump-packing, or in the pump-casing.

To insure perfect accuracy in the trials of steam fire-engines, there ought to be a tower sufficiently high to protect the stream from the resistance of the wind — the tower to be perfectly smooth and water-tight on all sides, with a water-tight tank at the bottom to retain the water. By such an arrangement, the exact height of the stream, as well as the quantity discharged in a given time, could be easily determined by measurement.

In making tests of fire-engines, it would be desirable to know the quantity of fuel consumed; but, as the circumstances under which fire-engines are used are not very favorable to economy, it would be impossible to compare the results with those obtained from engines used for different purposes.

INSTRUCTIONS FOR THE CARE AND MANAGEMENT OF STEAM FIRE-ENGINES AND BOILERS.

The careful maintenance in working order of steam fire-engines, and their judicious management when in service, are of the utmost importance, as they are essential to the development of the power so absolutely necessary to produce important and satisfactory results. Though steam fire-engines embrace quite a variety of designs and forms, yet the circumstances under which they operate are very similar; consequently, it may be possible to give some instructions for their care and management that will be beneficial to all those having them in charge.

When laying the fire, be sure and place plenty of shavings on the grate; then cover with dry kindling-wood and fill the furnace full with the ordinary blocks of wood used for that purpose. This will generally be sufficient to raise steam as soon as the fire is reached, that is, if the fire is lighted as soon as the alarm is given.

If coal be the fuel used, keep the fire thin, in order to prevent clogging in the furnace, and use as large lumps as possible; the best coal for steam fire-engines is clean cannel.

The water in the boiler when the engine is working, should stand at the third gauge-cock, and should never be allowed to be lower than between the first and second.

Never carry a higher pressure of steam than that actually necessary to work the engine, as extraordinary high-pressures are both dangerous and injurious to the boiler and its connections.

Use one pump continually for supplying the feed-water to the boiler, and regulate the supply so as to keep the water at the proper level, which will be of great assistance in maintaining a uniform pressure of steam.

If the steam does not generate sufficiently fast to work the engine, the variable-exhaust should be used; in fact, it should always be closed when the engine is started, and allowed to remain so until the pressure is sufficient, after which it should be opened.

If the steam generates faster than is necessary to work the engine, opening the furnace-door and increasing the feed-water supply will have a tendency to check it.

Avoid loud blowing off at the safety-valve or wasting steam as much as possible, as all such things are evidences of carelessness.

If it becomes necessary to stop the engine with a heavy fire in the furnace, open the furnace-door and uncover a part of the grate, in order to allow the cool air to pass up; then throw some lumps of fresh coal on the fire, and start the injector, if there be one attached to the engine.

Before starting the engine, open the discharge-gate and the drip-cocks of the steam-cylinder, and bring the engine moderately up to speed; all steam fire-engines perform better work when started slowly, besides being less liable to accident.

If the line of hose be very long, the throttle must be opened gradually, as if it is opened too suddenly, there is a liability to burst the hose.

The steam-cylinders and slide-valves of fire-engines should always be oiled when the engine returns from a fire, then it will be ready for service when required again. Good lard oil or melted tallow is the best lubricant for steam-cylinders.

All the moving parts should be thoroughly oiled before the engine is cleaned, so that the extra oil that escapes from the boxes or rubbing surfaces may be wiped up during the process of cleaning.

Never let waste fire collect under or near the engine,

as the wheels and woodwork would be liable to be burned.

All the revolving parts of the Silsby Rotary Engine should be kept thoroughly oiled when in use, and each time, after being used, a small quantity of good oil should be poured into the water-cylinder, and the engine turned round a few times, for the purpose of distributing the oil over the inner surface of the pump to prevent it from rusting.

The pump-valves should be frequently examined, at least once a month, for the purpose of seeing if they are all intact, or if the springs are of the proper tension to admit of the right lift. The lift of the valves of the pumps of steam fire-engines generally ranges from three-eighths to a half inch.

Be sure and take the engine off the springs before starting, and place it on them again when done working.

On returning from a fire thoroughly examine every part of the engine, whether it has been worked or not, as many of the parts that are exposed to a great strain are liable to be cracked or sprung by being run over rough streets.

When adjusting or repairing the engine or pump, if it becomes necessary to drive any of the parts together, a hammer or monkey-wrench never should be used unless a piece of sheet-copper or brass is interposed between the hammer and the parts to be driven. Any engineer can make a soft hammer for this purpose by filling a short piece of copper or brass tube with Babbit metal or lead.

The piston- and valve-rod stuffing-boxes should be frequently packed with some of the patent braided packing in use for that purpose. The fact is, steam fire-engines, or any other class of engines, are not packed nearly as often as they ought to be, as, when the packing loses its elasticity,

it is completely worthless, and by becoming dry and hard, it has a tendency to make the engine thump, and also to cut or flute the rods.

Before packing the glands, all the old packing should be carefully removed and the dust blown out; every engineer should provide himself with special tools for this purpose. A small steel bar about one-quarter inch in diameter and twelve inches long, drawn to a point at one end and having a loop or eye at the other, will effectually remove the old packing from the boxes; no rough instrument should ever be used for this purpose, as it will abrade or scratch the rod, which will in turn destroy the packing.

The packing for piston- and valve-rods should be a little larger in diameter than the gland is thick, in order to admit of being slightly flattened before being inserted in the box; it should be cut in lengths sufficient to encircle the rod, but the ends should not quite touch, as the packing ought to be allowed room to expand. It should be driven into the boxes with drifts made of hard wood about the thickness of the gland, slightly convex on one side and concave on the other; the rings should be inserted so as to break joints, and the stuffing-box screwed up so as to force the packing home to the bottom of the box, after which the gland may be slacked up for the purpose of allowing the packing to expand.

To find the right size of the packing for any stuffing-box, measure the diameter of the stem of the stuffing-box and the rod with the calipers; the diameter of the size of the packing will be half the difference between the diameter of the rod and the diameter of the box.

The very best description of packing may be rendered worthless by being ignorantly or injudiciously used.

If the leakage round the rods becomes excessive after the engine is newly packed, and the glands screwed up as

tight as they ought to be, if circumstances will permit, it is always better to stop and remove one or two of the rings and replace them in opposite directions, which will in a majority of cases stop the leaking.

Continual screwing up on the glands produces friction on the rods, which causes them to heat and destroy the elasticity of the packing; if it becomes necessary to frequently tighten the stuffing-boxes, it is always better to do it when the engine is standing still.

Pistons and valve-rod packing should always be kept in a clean place secure from dust, ashes, or sand.

The object of the safety-valve is to relieve the boiler from extraordinary pressure, and when the proper limit is attained, it speaks in a warning voice to the boiler attendant to "stop." The safety-valve is only a means of safety when well proportioned and well cared for after being put in use; it should never be weighed or screwed down for the purpose of carrying extraordinary pressure, as that is not necessary when the boiler and engine are in good order, and well proportioned for their work.

Safety-valves should be frequently and carefully ground on their seats. Pulverized glass, or the mud from a grinding-stone trough dried on a piece of sheet-iron or tin, is better for this purpose than emery.

The steam-gauge is another means of indicating approaching danger from over-pressure; and though it does not speak like the safety-valve, it is a silent and impressive monitor. Its steady moving hand on the face of the dial points with unerring aim to the danger.

The steam- and water-gauges of fire-engines should be tested at least twice a year by the direct application of a column of mercury, and no reliance whatever should be placed in so-called standard gauges, unless they are known to be made by manufacturers of undoubted reputation.

The glass water-gauge is one of the simplest as well as one of the most useful attachments of the steam-boiler; no other means of determining the height of water in steam-boilers can be so reliable.

Glass water-gauges should be frequently cleaned; this can be done by blowing out through the lower valve; but it may become necessary sometimes to use a swab, and in such cases the wood to which the swab is attached should be covered with cloth, as even wood touching the inside of the glass will produce an abrasion and cause the tube to break.

Before cleaning the engine, all the bolts, nuts, screws, and keys should be examined, in order to see that they are all tight and in good order, so as to prevent the necessity of handling them after the engine is cleaned.

To clean the bright work of the engine, whether iron or steel, use double or triple 0 crocus or emery cloth, which always should be rubbed in one direction, for any variation from the same direction will scratch the work. If the emery cloth be backed by a piece of an old felt hat or collar of a coat, it will last longer and do the work better.

Bright or finished work of engines should never be touched with the hand after being cleaned, especially in warm weather, as the acid in the perspiration will rust either iron or steel and dull the lustre of brass.

Receipts for cleaning brass and copper will be found in another part of this book.

It is not only the parts of the engine exposed to view that ought to be cleaned, but every part should show on examination that it was cared for. A handsomely kept engine, with all its parts clean and in good order, furnishes stronger evidence of an engineer's capabilities than a volume of written recommendations.

Every engineer in charge of a steam fire-engine should keep an extra set of pump-piston packing on hand, and, in fact, duplicates of all the different parts that he would be likely to need in an emergency. He should also have either in his possession, or in some accessible place, a monkey-wrench and wrenches to fit the different nuts of the engine and pump, a hammer, cold-chisels, calipers, cut-nippers, tin shears, dividers, spanners, monkey-jack, ratchet-drill, files, jack-knife, pinch-bars, etc., or any tool that would be likely to be needed in case of a break-down, or if it becomes necessary to adjust any part of the machine, which should be kept in conspicuous and accessible places, clean, and in good order; as all tools and appliances thrown aside or stowed away in obscure places are liable to be eaten up with rust and difficult to be found when wanted.

ENGINEERS.

Steam fire-engines should be in charge of practical engineers, not necessarily machinists, but men having a thorough knowledge of steam and steam machinery, and capable of adjusting all the different parts of their engines, and telling whether they are out of order or not. They should fully understand the causes of deterioration in the boilers of this class of machines, and the best means of protecting them from the evils which endanger their safety and limit their usefulness. They should have, if not a thorough, a tolerably good knowledge of hydraulics and hydraulic machines, and be capable of determining their capacity, and understanding the strains to which they are subjected when in use; these qualifications have been heretofore overlooked, though it seems rather strange that this should be so.

That the duties which this class of men is expected

to perform are of a very important character, all will admit; and it would be difficult to assign any reasonable cause why they should not be encouraged to qualify themselves for their faithful and intelligent performance; and while it is a fact, that many of the men in charge of steam fire-engines are capable and intelligent engineers, yet, unfortunately, they are not all so; nor will they ever be so, as a body, until they receive their appointments on real merit, instead of through political influence, and are retained in the service during good behavior, and encouraged to improve themselves. Every city should furnish the men in charge of steam fire-engines with a library of scientific books, and give them an opportunity to assist in repairing their engines and boilers, so that they may become efficient, if not expert, in their care and management; such an arrangement would incur a small expenditure of money at first, but this outlay would soon be amply returned by the increased intelligence and efficiency of the engineers, and the saving in the wear and tear of machinery, which would necessarily result from the more intelligent interest which they would take in their duties.

FIREMEN.

The subject of extinguishing fires has not heretofore received that careful and thorough investigation that its importance to every community so justly deserves, and it is only when that is done, and firemen trained in the duties of their calling, that the lives and property of the inhabitants of all large cities will be comparatively safe from the ravages of that terrible scourge — fire.

Firemen, to be efficient, should be thoroughly drilled and disciplined, as, without proper training, the most heroic valor and indomitable energy frequently are of no avail,

as it is a well known fact, that a few well trained men, accustomed to act together and relying on their own individual skill, can accomplish wonders, in consequence of their unerring action and the precision with which they perform every movement; while on the other hand, a want of judgment of the best method to be pursued, as well as a want of coolness and self-possession under trying circumstances, have, not unfrequently, not only frustrated the object to be accomplished, but even aggravated the destruction, instead of diminishing it. Numerous instances might be cited where, instead of being protected, property was actually destroyed by a reckless use of water.

The firemen of Paris have been more successful in extinguishing fires than those of any other city in the world. This arises from the fact, that they are all educated in the science of extinguishing fires, and thoroughly understand the plans of all public and nearly all private buildings. They are regularly drilled, ordered to patrol their various districts, in order to become acquainted with the location of each building, and the most favorable position to be taken in case of fire. They are also examined in the various duties they have to perform, the construction, use, and management of their engines and appliances, and instructed how to act in emergencies, whatever the circumstances and surroundings of the fire may be.

The success of firemen in extinguishing fires depends upon their intelligence, perseverance, and the character of the appliances under their control; but, unless they are properly trained for the duties of their calling, how can they be expected, even with the best appliances, to be successful?

None but healthy, active, energetic men, of good moral character, should be appointed as firemen; their reputa-

tion for sobriety and fitness for the position being the only recommendations required. Such men ought to be retained in the service during good behavior, and in case of sickness receive their full pay, and if by accident they should be rendered unfit for service, receive a life pension. Medals, or other tokens of approbation, should be given for brave and meritorious conduct. There also ought to be a Roll of Honor, on which the names of men who have lost their lives in their efforts to save those of others, should be enrolled.

USEFUL INFORMATION FOR ENGINEERS AND FIREMEN.

Steam fire-engines are simply hydraulic machines similar to steam-pumps, and the conditions involved in their employment are precisely the same. They are also steam-engines with their machinery adapted to a special purpose, it being perfectly immaterial whether they are movable or stationary. Their means of locomotion is only a matter of convenience.

The result of the working of the steam fire-engine may be measured by the hydraulic effect, and the power utilized may be determined by measuring the quantity of water delivered.

The reason why steam fire-engines do not work with uniform satisfaction on all occasions, may be attributed either to leakage in the suction-hose, in the couplings, the pump-piston, or joints, or to the fact that one or more of the valves are stuck open or held from their seats by some substance, such as dirt, rags, or paper.

The cause of the shaking of the discharge-hose arises from a want of capacity or leakage in the air-vessel on the discharge part of the pump. The shaking of the suction-

hose is also caused either by an insufficient air-vessel on the receiving part of the pump, or by leakage of the same.

The area of the steam-cylinder in some of the most efficient steam fire-engines in the country is about three times the area of the pump.

A fire-engine in good order will deliver as much water when lifting from a river or well, providing the lift is not over twenty feet, as it will do when receiving her water from a fire-plug at ordinary city pressure.

The objections to high speed in steam fire-engines is the liability to get them out of repair or break down; the same objection will apply to high speed in any class of machines.

The speed of fire-engines must always have a very narrow limit, in consequence of the difficulty of managing the delivery-hose, and its liability to burst at high speed. The range must be between 200 and 300 feet per minute; between these two speeds the maximum results will be obtained; but short-stroke, quick-running engines will raise water better than those that run slowly.

A steam fire-engine will force water to whatever distance the pressure on the pump will carry it; but it will draw water only so far as the vacuum created by the pump in the suction-pipe will cause the water to rise, which is about 30 feet in the best cases; this varies, of course, according to the condition of the pump, the hose, etc.

A nozzle of a bad form, or one unsuited to the velocity of the stream of water, diminishes the height and distance reached by the water to a great extent.

If the stream of water becomes spread, so as to present a larger sectional area than that of the nozzle through which it passes, it will be found that the range will be proportionally diminished.

If the water becomes spread or divided when issuing from the nozzle, no matter how close to the nozzle this

division or spreading may take place, it will be found that the power of the stream is instantly destroyed.

The delivery-hose used with fire-engines is generally too small; better results would be obtained from hose of a larger diameter; but the diameter cannot be increased beyond certain limits, as every increase of diameter tends to weaken the hose.

Hose badly made, with couplings contracting the waterways, instead of keeping them of the same size as the internal diameter, is a very powerful means of diminishing the effect of the force expended on the pump.

The form of nozzle by which water is discharged from a force-pump, influences largely the amount of the discharge. The form of the suction-pipe by which the water enters a pump influences its efficiency, but by uniting these two conditions in a scientific manner, a discharge may be obtained greater than that due to the sectional area of the pipe.

By increasing the diameter of a pipe, an enormous gain is secured in the transmission of water or other liquids, as an increase of diameter tends to diminish the friction.

The friction in a small tube is so great that a tube twice the diameter will deliver five times the quantity of water.

A pipe two inches in diameter, 100 feet long, will deliver but one-fourth the quantity of water that a pipe two inches in diameter and two inches long will with the same pressure.

A smooth lead pipe will deliver more water than a wooden pipe of the same diameter.

The flow of water in pipes of any diameter will be sensibly affected by the roughness or smoothness of their interior surfaces.

Pipes fully as large as the pump connections should be used in all cases, and where it becomes necessary to use long or crooked pipes, they should be even larger.

Short bends and angles in pipes should be avoided as much as possible, as they retard the flow of the water; but when they have of necessity to be used, they should be as large as practicable.

The capacities of pipes for delivering water vary as the squares of their diameters, and their delivery varies nearly as the square root of the head minus the friction.

Water under the most favorable circumstances would rise through the atmosphere in a jet to a height of about two-thirds of the head. Friction, of course, would reduce this result somewhat.

To throw a solid jet of water an extra distance or height in a given time, and with a given pressure, the bore through which it is forced should be scientifically proportioned and highly finished.

The principal causes of shaking in horizontal fire-engines is owing to the horizontal motion of the piston, want of rigidity in the frame, and leakage in the air-vessel.

Roughness in the hose and in the passages of steam fire-pumps, especially at high velocities, has a great tendency to diminish the theoretic duty due to such machines.

The distance at which a jet discharged from a nozzle begins to scatter and break into spray by the resistance of the air in its passage through it, depends upon the velocity of the jet.

The length of the discharge-hose makes a great difference in the quantity of water delivered, as, when they are very long, the power of the engine is used up by the friction of the water passing through the hose.

The speed at which a steam fire-engine runs, depends very much on the following three factors: the length of the suction-hose, the length of the delivery-hose, and the

size of the nozzle. These three points determine the amount of water which can be delivered by the pump or discharged from it, and nothing can be gained by running an engine faster than it is capable of receiving and discharging the water.

The quantity of water which any pump will lift or discharge may be estimated by multiplying the area of the piston by the speed; but this rule infers that the pump is fully supplied, and the water thoroughly discharged at every stroke.

The movement of the piston of any pump should not be so rapid as to run away from the water or to prevent the valves from seating.

Reciprocating pumps should always be double-acting, as they work more steadily and economically than if single-acting.

All pumps should be so constructed as to require as little packing as possible.

A well designed steam- or fire-pump should work without jarring, and without communicating motion to other parts of the machine.

Pumps, to be efficient and durable, should be so designed as to be capable of pumping water containing impurities without being affected by grit, dirt, or corrosion.

Any well made steam fire-engine or fire-pump ought to lift water 25 feet without priming.

PAID AND VOLUNTEER FIRE DEPARTMENTS.

Paid fire departments have nearly superseded the volunteer system in almost all the cities in the country, and so far have given very satisfactory results, so much so, that even those who offered the most stubborn opposition to their establishment, would not now, if they had an op-

portunity, vote to re-establish the volunteer system. Many of the abuses which from time to time crept into that system, and grew up under it, have been swept away by the establishment of the paid fire departments, as the number of fires has decreased, and engine-houses have been transformed from loafing places to establishments where the routine of duty is enforced and obedience substituted for insubordination.

The Paid Fire Department of Philadelphia, since its inauguration, has fortunately been under the command of efficient chief engineers, and in consequence has given universal satisfaction. Its members are generally men possessing physical capacities which accord with the character of the work to be performed, and trained to meet every emergency so far as experience and intelligence can suggest. A fact creditable to the members of this department is, that in the performance of their arduous duties, they are not excelled by any other department under the city government.

But while doing ample justice to the workings of the paid system, no word must be said derogatory to the character or memory of the volunteer firemen, either living or dead, as they were, in general, useful, intelligent, and brave men, who would not intentionally sanction or encourage wrong. They, in their anxiety to keep their companies up to a good, efficient, working standard, were very often compelled to associate with disreputable men. What calling could be more honorable, or command more respect in the estimation of all right-minded men, than that of Volunteer Firemen, who discharged all their rigorous and arduous duties—frequently perilling life and limb, or staring death in the face in the most dangerous form, and often laying down their lives to save those of others—without even the promise of a reward.

The hardy seaman pants the storm to brave,
For beck'ning Fortune woos him to the wave;
The soldier battles 'neath his smoky shroud,
For Glory's bow is painted on the cloud;
The Fireman also dares each shape of death —
But not for Fortune's gold nor Glory's wreath.
No selfish throbs within their breasts are known;
No hope of praise or profit cheers them on.
They ask no meed, no fame; and only seek
To shield the suffering and protect the weak!
For this the howling midnight storm they woo;
For this the raging flames rush fearless through;
Mount the frail rafter — thrid the smoky hall —
Or toil, unshrinking, 'neath the tottering wall.
Nobler than they who with fraternal blood
Dye the dread field or tinge the shuddering flood,
O'er their firm ranks no crimson banners wave;
They dare — they suffer — not to slay — *but save!*

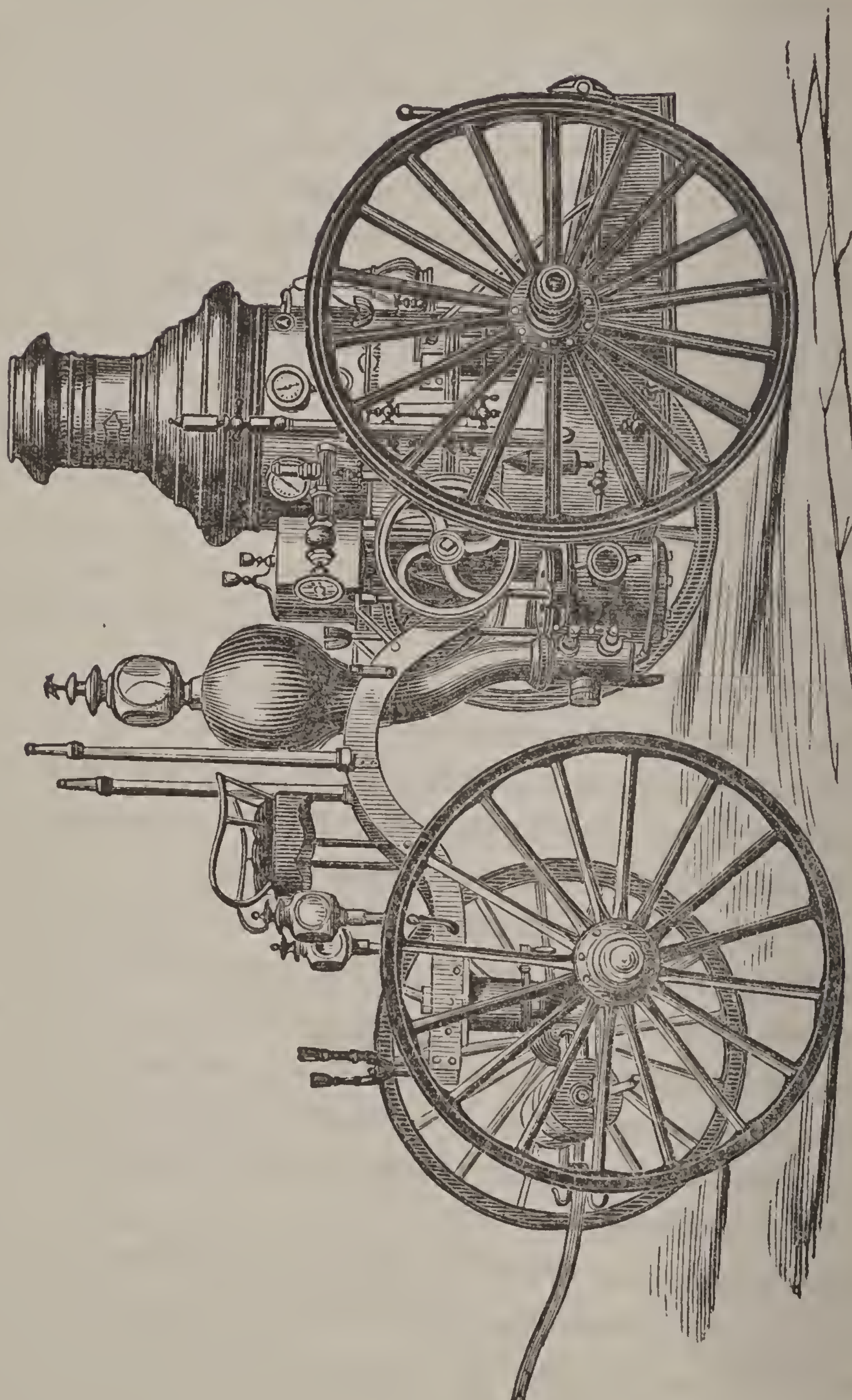
The parade of the volunteer firemen held in Philadelphia, in 1865, was one of the grandest and most imposing demonstrations ever witnessed on this continent. No potentate of the Old World could command such a turn-out, either in men or equipments. There were more than thirty thousand volunteer firemen in line, all of whom were dressed in elegant uniform; each company had its own steamer, hand engine, or hose carriage. There were sixty-seven steam fire-engines, twenty hand engines, one hundred and twenty hose carriages, nineteen hook and ladder carriages, and twenty-seven ambulances. There were eleven bands of music, each band consisting of from thirty to sixty members; many of the fire companies mustered between five and six hundred men. It took the procession nearly four hours to pass a given point. Such a demonstration was unprecedented, and could not be got up in any other nation in the world except this.

FIRE-ALARMS.

It is an indisputable and well-known fact, that the quicker a fire can be discovered and taken in hand, the more easily it can be extinguished, the less severe the damage or loss will be; consequently, in all large cities of this country an efficient telegraph arrangement has been carried out by which the loss of time incurred in running several squares to the nearest station, as is frequently the case in most European cities, has been done away with. Each city is divided into a number of districts, each of which is provided with as many telegraph alarm-boxes as are considered sufficient to insure a speedy and immediate alarm, all alarms being transmitted to the central station, and from thence to the district in which the fire has occurred; and as the alarm-boxes are self-regulating, when one is struck no other alarm can be given until the first has reached its destination.

On the first alarm being struck, a certain number of engines and hook and ladder trucks proceed to the fire; if it is a large fire, a second alarm is given, when as many more engines and hook and ladder trucks proceed to the fire, and so on until, if necessary, a general alarm is given, when the whole department turns out. It is only in case of terrible conflagrations that it becomes necessary to give a general alarm. Such an occurrence has not taken place since the establishment of the Paid Fire Department in this city.

Against the cost of carrying out an efficient and reliable fire-alarm telegraph there can be no reasonable argument offered, as it would be found that if only one ordinary fire was prevented by this means, the saving would more than pay for the establishment of a perfect system that would secure all that might be desired.



THE GOULD STEAM FIRE-ENGINE.

THE GOULD STEAM FIRE-ENGINE.

The Gould Steam Fire-Engine, manufactured by W. H. Lang, Goodhue & Co., Burlington, Vt., is shown on the opposite page. The boiler is a vertical tubular with submerged smoke-flues and tapering fire-box. By the latter arrangement, a larger grate surface is secured than could otherwise be obtained in any other boiler of the same proportions. The strains induced by the expansion and contraction of the furnace-plates are also very much modified, and in consequence of the water-leg being larger at the top than at the bottom, a more perfect circulation of the water is attained than if it was straight. The smoke-box is conical in shape and made from one sheet, which gives it the advantage of great strength and increased draught. It occupies but little space, and requires but one joint in its connection with the boiler.

The feed-water is heated by passing through the fire-box, a circulating-valve being placed on the outside between the boiler and heater, so that when the feed-pump is stopped, a perfect circulation can be established between the heater and the boiler. This has the advantage of preventing the latter from being burned or injured in case the water should become low, or if the feed-pump failed, or it became necessary to take out the check-valve to remove any substance that would keep it from its seat and prevent its working, which is very often the case.

These boilers have an uncommonly large heating surface and steam room in proportion to the work to be done by the engine, consequently they steam very freely, being capable of raising sufficient steam from cold water, in from three to four minutes' time, to play through a hundred feet of hose. They are said to be very durable and economical. The shells are made of the best

steel plates, and the tubes of the finest quality of copper. Every precaution has been taken to make them durable, efficient, and strong.

The engines are vertical, reciprocating; the steam-cylinders resting on columns which are attached to the crane-neck frame and to the boiler. In the single engine the steam-chest faces to the side, and in the double engine to the front, which arrangement affords easy access to the valves in case it should become necessary to examine or adjust them. The pumps are hung on the lower ends of the same columns which support the steam-cylinders, and, like the latter, are attached to the boiler. They consist of a cylinder, casing, and valve-plate; and in consequence of this latter being in one piece, it can be removed for the purpose of examining or renewing the valve-packing by simply taking off the cover of the water-cylinder; and the arrangement is so simple, that the valves can either be repaired or replaced by a new set in a very few minutes.

The arrangement of the valves in this pump admits of a larger suction and discharge with less lift of valve, and consequently a better supply of water, and less loss induced by friction in the passages, than could be obtained by any other design that might be adopted. The valves are metallic with rubber packing, and are guided in their movements by knife-edges, which effectually prevents them from being kept open by any substance that may be drawn in with the water; when worn out, the packing can be replaced at a very small cost. The pump-plunger, like nearly all others, is packed with leather, as it is more simple, efficient, and economical than any other material that could be used for that purpose.

There are five sizes of these engines manufactured, but the same outline is preserved in them all. They are made of the best material, and fitted in the most accurate and

thorough manner; all the parts are made to standard gauges, and are always duplicated for the same class, so that any broken parts can be replaced at short notice. The Gould Steam Fire-Engine has an excellent reputation for durability and economy. In fact, the design and general arrangement of the parts of these engines are highly creditable alike to the inventor and manufacturer. Each engine is furnished with the following supplies and attachments: 20 feet of suction-hose, 1 brass strainer for same, 1 hydrant connection, 1 steam-whistle, 1 steam- and 2 water-gauges, 2 discharge-pipes, full set of nozzles, 2 firemen's hand lanterns, 2 reflector lamps, 1 signal lamp, 1 jack-screw, 2 oil cans, shovel and poker, all the small tools required for the adjustment of the different parts of the engine.

ROUTINE OF BUSINESS IN PAID FIRE DEPARTMENTS.

The following is the order of business in the Paid Fire Departments in all the principal cities in the United States:

The Foreman of each company musters his men in quarters and calls the roll at 8 o'clock A. M. All members present are required to show or account for all property or devices belonging to the department in their care or possession. All being found correct, the company break ranks and proceed to duty.

The Foreman makes out his morning report and forwards it to head-quarters. The engineers proceed to clean their engine, the drivers to clean and care for the horses, the remaining members to clean quarters, such as scrubbing floors, white-washing, splitting wood, etc.

At meal hours, one-half of the members proceed to their meals, although in some instances they go by two's.

There is always on the first floor in quarters one man

in full uniform, for the purpose of giving information to visitors and sounding the alarm-gong to call the members to duty in case of a fire. It is also his duty to open the doors leading to the stables and allow the horses to proceed to their proper places to be hitched,* they being always in harness except when the drivers are cleaning them; and even then the harness is only taken off one at a time, in order to cause as little delay as possible in case an alarm should be sounded.

The horses being hitched, the driver takes his seat, and each member has his position by numbers, the engineer standing on the platform with torch in hand, ready to apply it to the shavings in the furnace as soon as the engine passes out of the door. One hoseman rides on the engine to assist the engineer in making his connections with the plug. The remaining members take their positions on the tender, which follows in the wake of the steamer about twenty or thirty yards.

When they arrive at the fire, the foreman, or officer in command, proceeds to the premises on fire, the driver stops his engine at the nearest fire-plug, unhitches his horses and leads them to a place of safety, remaining with them. The engineer takes the suction-hose and makes the connection between the fire-plug, and is then ready for service.

The tender-driver stops at the engine and allows the men to dismount, when they take a turn of the hose round one of the spokes of the forward wheel of the engine, while the tender-driver proceeds in the direction of the fire, allowing the hose to unwheel as he goes; when a sufficient quantity is unwheeled, the members detach it, put on the pipe and stand waiting orders; in the meantime the driver finds a place of safety for his horse and tender, in the rear of the engine, in order that the engineer and stoker may see what

* In some instances the horses are unhitched and the doors opened by electric appliances.

equipments are borrowed from the tender by other companies.

The fire being extinguished and the company's service no longer needed, the officer in command issues orders to "take up;" the engineer stops the engine, draws the fire, disconnects the suction-hose, closes the fire-plug, disconnects the discharge-hose, and puts all tools in their proper places; in the meantime the driver leads his horses back to the engine.

The tender is next sent for, the men disconnect the hose and commence to reel them up, the tender moving towards the engine. When all the hose are reeled up, the officer in command gives orders to proceed to quarters, no member riding except the drivers. When they arrive at quarters, the engine-driver stops in front of the door, unhitches his horses, and leads them to the stable.

All the members assist in putting the engine into quarters, after which the firemen and engineers clean the furnace, recharge it with shavings and wood, attach the heater-pipe, and make everything ready in case of an alarm. The hosemen unreel the hose, replace them with dry hose, and proceed to wash those that were in use at the fire.

The member or officer having charge of the house, enters on the blotter the name of the street and number of the house where the fire occurred, whether insured or not, cause of the fire, etc.

In every six days each member is allowed twenty-four hours' leave of absence. No two officers are off at one time.

SALVAGE BRIGADES AND INSURANCE PATROLS.

In most of the large cities of Europe they have organizations called Salvage Brigades, which assist in protecting

insured property from fire, and which, as a compensation for their services, receive salvage in proportion to the amount of property they are instrumental in saving from damage either by fire or water. In this country, instead of Salvage Brigades, we have Insurance Patrols, which are employed and paid by a certain number of Insurance Companies to look after insured property in case of fire. The Insurance Patrol of Philadelphia consists of a captain and sixteen men; they have a steam fire-engine and truck, and all the necessary appliances to be used in extinguishing fires; they attend all the fires that occur in the city; but their engine is only used for pumping out cellars where insured property is stored, and which is likely to be damaged by water. The Insurance Patrol is very liberally paid, and is not in any way connected with the fire department.

FIRE-HOSE.

Canvas was one of the earliest materials used as hose for fire-engines, but its usefulness for that purpose had a very short existence, and it is now nearly, if not altogether, super-

seded by leather, which in turn is about to be superseded by gum or India-rubber. Good leather hose has many advantages over canvas, as it is stronger and capable of standing rougher usage on streets, roads, or uneven surfaces; but it has the disadvantage of being leaky and rough on the inside, which, as a matter of course, interferes with the free flow of water, and which, therefore, diminishes the quantity due to a given diameter under a given pressure. Leather hose requires to be frequently oiled to prevent them from getting dry, but if from neglect, or any other cause, they should become hard, the only way to soften them is to soak them in warm water until softened; then they should be oiled, and the oil thoroughly rubbed in with the hand, after which they may be hung up in an airy place.

Gum hose has the advantage over leather of being perfectly smooth on the inside, and consequently capable of delivering more water with the same pressure and diameter. It requires less care than leather, and, when properly made, is equally as strong, if not stronger; but it is incapable of standing as rough usage, and sustaining more injury when trod on or driven over.

Canvas hose is coming into very general use, and answers a very good purpose; it is light and strong, and when properly treated quite durable; but it is incapable of standing as rough treatment as either leather or gum, though for some purposes, and under some circumstances, it is superior to either. The first cost of either is about the same.

HOSE-COUPLINGS.

Contrivances for effecting an easy and rapid connection and disconnection between different lengths of hose and the pumps or water supply was an early necessity in connection with machines for extinguishing fires, as the time

consumed in fastening a badly designed or illy made coupling added very much to the threatening danger. Engines were often forced to remain inactive while fires were gaining ground, and the best efforts of firemen to extinguish them were frustrated, in consequence of being unable to easily connect or disconnect their hose. The screw was one of the earliest devices for this purpose, and is the most generally used at the present time, and when well made, is tighter and safer and stronger than any of the many appliances in use for this purpose.

Its great drawbacks are, 1st, its enforced slowness in making the connection; 2d, being male and female, it does not admit of being coupled at either end at will; 3d, that it is liable to be mashed or knocked out of cylindrical form, which renders it useless; 4th, the liability of the screw to foul or "cross the thread," which effectually ruins it. This latter difficulty, however, has been successfully overcome in the "Button" coupling, as a guide or sleeve on the point of the male coupling prevents the possibility of crossing the threads when making the connection. But the greatest annoyance arises from the difference in the number of threads to the inch in the screw-couplings of different manufacturers. What is needed to render the screw-coupling what it should be, is the adoption, by manufacturers, of a national or standard thread, and the strict enforcement of such an understanding by the chief engineers of all fire departments.

Snap- and slide-couplings are in very general use, and though not always perfectly tight, have the advantage of being easily connected and disconnected, which is a consideration of great importance; but for suction-hose they are not at all reliable. They may be described as follows:

The Silsby has a U-shaped head on the female side, into which the male, which has a circular end with a fillet cor-

responding to a groove in the U, is slid, and jammed against the washer by screwing the U further back on the shank. This coupling has the advantage of being easily and quickly connected, and it is capable of being put together by a common spanner. Its chief drawbacks are its weight, and the fact that it is not reversible.

The Gaylord coupling has a circular channel on the outside of the male, which is inclined, and is placed against the face of the washer in the female, and jammed by means of exterior nuts. Like the Silsby, it is heavy and not reversible.

The Universal coupling has two lugs projecting on each half from inclined planes, which lock those on the other half. It cannot be claimed to be perfectly tight, but it has the advantage of being reversible. It is also very simple and not easily injured, though it requires a special spanner.

The Siamese or Y connection. This contrivance enables two streams to be thrown on the burning building without stretching two lines of hose from the engine, which is a great advantage, especially where there is an insufficiency of hose, as is frequently the case. The Siamese can also be arranged for connecting a line of hose from two engines, so that the combined power of both can throw a stream of water from one nozzle.

DIMENSIONS OF FIRST AND SECOND CLASS MODERN STEAM FIRE-ENGINES.

THE AMOSKEAG—FIRST CLASS.

Height from floor to top of smoke stack	8 ft. 10 ins.
Length over all, including tongue	23 ft. 8 ins.
Diameter of boiler	2 ft. 8 ins.
Diameter of pumps	$4\frac{1}{2}$ ins.
Stroke of same	8 ins.
Diameter of steam-cylinders	$7\frac{5}{8}$ ins.
Number of discharge-gates	2
Capacity in gallons per minute	900
Weight, about	6500 lbs.

THE AHRENS — FIRST CLASS.

Height from floor to top of smoke-stack	9 ft. 6 ins.
Length over all, including tongue	22 ft.
Diameter of boiler	38 ins.
Diameter of pump	$6\frac{5}{8}$ ins.
Stroke of same	8 ins.
Diameter of steam-cylinder	11 ins.
Number of discharge-gates	2
Capacity in gallons per minute	800
Weight, about	7300 lbs.

THE CLAPP & JONES — SECOND CLASS.

Height from floor to top of smoke-stack	8 ft. 6 ins.
Length over all, including tongue	23 ft.
Diameter of boiler	38 ins.
Diameter of pumps	$4\frac{5}{8}$ ins.
Diameter of steam-cylinders	8 ins.
Stroke of engine	8 ins.
Number of discharge-gates	2
Capacity in gallons per minute	600
Average weight	6800 lbs.

THE GOULD — FIRST CLASS.

Height from floor to top of smoke-stack	8 ft.
Length over all, including tongue	23 ft.
Diameter of boiler	40 ins.
Diameter of pump	6 ins.
Diameter of steam-cylinder	9 ins.
Stroke of engine	7 ins.
Number of discharge-gates	3
Capacity in gallons per minute	1000
Average weight	6500 lbs.

THE SILSBY — FIRST CLASS.

Height from floor to top of smoke-stack	9 ft. 4 ins.
Length over all, including tongue	23 ft.
Diameter of boiler	40 ins.
Diameter of pump	$8\frac{1}{2}$ ins.
Diameter of "rotary" engine	$13\frac{1}{2}$ ins.
Number of discharge-gates	2
Number of gallons per minute	700
Weight, about	7500 lbs.

THE BUTTON—FIRST CLASS.

Height from floor to top of smoke-stack..........	9 ft.
Length over all..	16 ft.
Width of engine..	6 ft.
Number of discharge gates................................	4
Capacity in gallons per minute	700
Weight, about	6000 lbs.

LA FRANCE PISTON FIRE-ENGINES.
DOUBLE PUMP AND STEAM CYLINDER.—IN FOUR SIZES.

	EXTRA 1st SIZE.	1st SIZE.	2d SIZE.	3d SIZE.
Height over all........	9 ft. 6 in.	9 ft. 6 in.	9 ft. 6 in.	9 ft. 4 in.
Length over all.........	25 ft.	24 ft. 6 in.	24 ft. 6 in.	24 ft. 3 in.
Width over all (ordinarily)	6 ft. 3 in.	6 ft.	6 ft.	6 ft.
Weight, without supplies, about.	8200 lbs.	7500 lbs.	6700 lbs.	5800 lbs.
Capacity, Gals. per min.,	*1100	850	700	600
Diam. of boiler.........	36 x 66 in.	36 x 60 in	32 x 60 in.	30 x 60 in.
Diam. of pumps......	$5\frac{3}{4}$ in.	$5\frac{1}{4}$ in.	$4\frac{5}{8}$ in.	$4\frac{7}{8}$ in.
Stroke of pumps.......	8 in.	8 in.	8 in.	6 in.
Diam. of steam-cyl...	$9\frac{3}{4}$ in.	$8\frac{3}{4}$ in.	$7\frac{3}{4}$ in.	8 in.
Discharge gates........	4	4	2 to 4	2 or 3

☞ ***The extra first-class engine will throw a 1¾ inch stream 300 feet, or a 2 inch stream 275 feet.***

LA FRANCE ROTARY FIRE-ENGINES.—CLASS "A."
IN SIX SIZES.

	1st SIZE.	2d SIZE.	3d SIZE.
Height over all....................	9 ft. 2 in.	9 ft. 2 in.	9 ft.
Length over all.................	22 ft. 10 in.	22 ft.	21 ft.
Width over all (ordinarily),	6 ft.	6 ft.	6 ft.
Weight, without supplies, about,	7800 lbs.	7000 lbs.	6500 lbs.
Capacity, gallons per min...	850	700	600
Diameter of boiler	40 x 60 in.	38 x 60 in.	36 x 60 in.
Discharge gates...............	2	2	2

	4th SIZE.	5th SIZE.	6th SIZE.
Height over all	9 ft.	8 ft. 11 in.	8 ft. 11 in.
Length over all.................	20 ft. 10 in.	20 ft. 5 in.	20 ft. 3 in.
Width over all (ordinarily)	6 ft.	6 ft.	6 ft.
Weight, without supplies, about,	5800 lbs.	4800 lbs.	4200 lbs.
Capacity, gallons per min...	500	400	350
Diameter of boiler............	34 x 60 in.	32 x 60 in.	30 x 60 in.
Discharge gates................	2	2	2

HORIZONTAL DISTANCES THROWN BY MODERN STEAM FIRE-ENGINES.

THE AMOSKEAG FIRST CLASS.

Location.	Date of Trial.	No. of Streams.	Diameter of Nozzles.	Feet of Hose in each line.	Horizontal Distance Thrown.	
			Inches.		Feet.	Ins.
New Orleans, La....	Apr. 30, 1867...	1	$1\frac{1}{4}$	100	304	3
Syracuse, N. Y.......	June 29, 1867...	1	$1\frac{1}{4}$	50	295	...
Harrisburg, Pa......	Sept. 2, 1867....	1	$1\frac{3}{8}$	50	316	11
Adrian, Michigan...	Oct. 3, 1867.....	1	$1\frac{1}{4}$	50	316	...
		2	$1\frac{1}{8}$	50	235	...
Syracuse, N. Y.......	Oct. 9, 1867.....	1	$1\frac{1}{4}$	50	282	...
		2	$1\frac{1}{8}$	50	240	...
Oshkosh, Wisconsin.	Dec. 26, 1867...	1	$1\frac{1}{4}$	450	272	...
		2	1 & $1\frac{1}{4}$	450	225	...
Des Moines, Iowa...	May 2, 1868.....	1	$1\frac{1}{4}$	50	280	...
		1	$1\frac{3}{8}$	50	254	...
New Orleans, La....	June 26, 1868...	1	$1\frac{1}{4}$	100	311	8
		2	$1\frac{1}{8}$	100	230	3
Newport, Ky.........	July 1, 1868....	1	$1\frac{1}{4}$	50	325	...
Titusville, Pa........	Oct. 25, 1868...	1	$1\frac{1}{4}$	50	300	...
Saco, Maine...........	Aug., 1871......	1	$1\frac{1}{4}$	50	286	...
		2	$1\frac{1}{8}$	50	234	...
New Orleans, La....	Aug. 17, 1873...	1	$1\frac{3}{8}$	50	311	$9\frac{1}{2}$
		1	$1\frac{3}{8}$	100	294	11
New Orleans, La....	Dec. 27, 1874...	1	$1\frac{1}{2}$	100	321	4

HORIZONTAL DISTANCES THROWN BY THE SILSBY FIRST-CLASS STEAM FIRE-ENGINE.

Location.	Date of Trial.	No. of Streams.	Diam. of Nozzles.	Feet of Hose in each line.	Horizontal Distance Thrown.	
			Inches.		Feet.	Ins.
Worcester, Mass.....	May 13, 1866...	1	1	3000	150	...
Atlanta, Ga..........	Feb. 22, 1872...	1	$1\frac{1}{4}$	100	284	4
Wilmington, Del....	Feb. 17, 1873...	1	$1\frac{1}{4}$	50	283	...
Sherbrooke...........	May 25, 1875...	1	$1\frac{1}{4}$	50	274	...
Lake City, Minn....	May 26, 1875...	1	$1\frac{1}{4}$	100	278	...
" " "	" " " ...	2	$1\frac{1}{8}$	1450	161	6
Smith's Falls, Ont...	June 30, 1875...	1	$1\frac{1}{4}$	50	263	...
" " " ...	" " " ...	3	$\frac{7}{8}$	450	173	...
Chicago, Ill...........	June 22, 1875...	1	$1\frac{1}{4}$	100	293	6
" "	" " " ...	2	$1\frac{1}{3}$	300	205	10
Manchester, Iowa...	Dec. 21, 1875...	1	$1\frac{1}{8}$	1500	192	...
" " ...	" " " ...	1	$1\frac{1}{4}$	500	261	8

HORIZONTAL DISTANCES THROWN BY THE AHRENS STEAM FIRE-ENGINE.

Location.	Date of Trial.	Number of Streams.	Diameter of Nozzles.	Feet of Hose in each Line.	Horizontal Distance Thrown.
			Inches.		Feet.
Indianapolis, Ind...	Jan. 7, 1876....	1	$1\frac{3}{4}$	100	249
" "	Nov. 11, 1875..	1	$1\frac{1}{2}$	500	275
" "	July 22, 1875..	1	$1\frac{3}{8}$	100	302
St. Louis.............	April 6, 1875...	1	$1\frac{1}{2}$	100	290
Chattanooga, Tenn.	June 14, 1875..	1	$1\frac{1}{8}$	100	270
Nashville, Tenn.....	Dec. 30, 1875...	1	$1\frac{1}{8}$	200	271
Waverly, Ohio	Nov. 9, 1875 ...	1	$1\frac{1}{8}$	100	260
" "	" " ...	1	$1\frac{1}{8}$	1000	211
Cincinnati, Ohio.....	May 3, 1875 ...	1	$1\frac{1}{8}$	1000	208

HORIZONTAL DISTANCES THROWN BY THE BUTTON FIRST AND SECOND CLASS.

Location.	Date of Trial.	Class of Engine.	No. of Streams.	Diameter of Nozzles.	Feet of Hose in each Line.	Horizontal Distance Thrown.
				Inches.		Feet.
Harrisburg, Pa......	June, 1866...	1st class	1	$1\frac{1}{2}$	50	301
" "	" 1867...	"	1	$1\frac{3}{8}$	50	326
Cohoes, N. Y.........	Aug., 1867...	2d class	1	$1\frac{1}{4}$	100	267
" "	" " ...	"	2	$1\frac{1}{4}$	100	210
Elizabeth, N. J......	June, 1868...	"	1	$1\frac{1}{8}$	100	263
" "	Sept., 1868...	"	1	$1\frac{1}{8}$	100	265
Lebanon, Pa..........	" " ...	1st class	1	$1\frac{1}{4}$	100	$300\frac{1}{2}$
Lambertville, N. J..	Dec., 1869....	2d class	1	$1\frac{1}{4}$	100	290
" " ..	" "	"	1	$1\frac{1}{2}$	100	250
Steubenville, O......	May, 1870....	"	1	$1\frac{1}{8}$	100	275
" "	" "	"	1	$1\frac{1}{8}$	100	275
Saratoga Sp'gs, N.Y.	Sept., 1871...	"	1	$1\frac{1}{4}$	250	285
Rhinebeck, N. Y....	Oct., 1871.....	"	1	$1\frac{1}{4}$	1000	186
New Castle, Pa......	Sept., 1873...	"	1	$1\frac{1}{4}$	1450	219
Peabody, Mass.......	July, 1874....	"	4	$\frac{7}{8}$	350	180
Aurora, Ill...........	March, 1875.	"	1	$1\frac{1}{8}$	1000	204

HORIZONTAL DISTANCES THROWN BY THE GOULD FIRST AND SECOND CLASS STEAM FIRE-ENGINES.

Location.	Date of Trial.	Class of Engine.	No. of Streams.	Diameter of Nozzles.	Feet of Hose in each Line.	Horizontal Distance Thrown.
				Inches.		Feet.
New Orleans, La..	Sept. 14, 1873	1st class	1	$1\frac{1}{2}$	100	314
" " " ..	May 10, 1873	"	1	$1\frac{1}{2}$	100	320
Wilmington, Del..	Aug. 23, 1874	"	1	$1\frac{1}{2}$	100	$328\frac{1}{2}$
" " ..	" " "	"	1	2	100	209
" " ..	" " "	"	2	$1\frac{1}{4}$	100	262
" " ..	" " "	"	1	$1\frac{1}{2}$	100	$354\frac{1}{3}$
Chicago, Ill.........	Sept. 25, 1874	"	1	$1\frac{1}{2}$	100	310
" "	" " "	"	2	$1\frac{1}{4}$	500	$253\frac{1}{2}$
New Orleans, La..	Dec. 29, 1872	2d class	1	$1\frac{1}{4}$	100	251
" " " ..	May 4, 1873.	"	1	$1\frac{1}{4}$	100	256
" " " ..	" " "	"	2	$1\frac{1}{8}$	100	$152\frac{1}{2}$
" " " ..	" " "	"	1	$\frac{7}{8}$	1000	$165\frac{1}{4}$
" " " ..	July 20, 1873	"	2	1&$1\frac{1}{8}$	100	$255\frac{2}{3}$
" " " ..	Aug. 29, 1874	"	1	$1\frac{1}{4}$	100	262

DISTANCES THROWN BY CLAPP & JONES' SECOND, THIRD, AND FOURTH CLASS STEAM FIRE-ENGINES.

Location.	Date of Trial.	Size of Engine.	Diam. of Nozzles.	Feet of Hose in each line.	Horizontal Distance Thrown.	
		No.	Inches.		Feet.	Ins.
Columbia, Pa.........	Nov., 1868......	2	$1\frac{1}{4}$	100	304	...
Detroit, Mich.........	May, 1871.......	2	$1\frac{1}{4}$	100	325	...
Mobile, Ala..........	Nov., 1871......	2	$1\frac{1}{4}$	100	294	...
Wilmington, Del....	March, 1873....	2	$1\frac{1}{4}$	100	302	7
New Bedford, Mass.	Sept., 1873......	2	$1\frac{1}{4}$	1000	235	...
Wilmington, Del....	" "	2	$1\frac{1}{4}$	100	301	8
Indianapolis, Ind...	July, 1874.......	2	$1\frac{1}{4}$	500	284	...
" " ...	" "	2	$1\frac{1}{4}$	100	298	...
Chicago, Ill..........	Sept., 1874......	2	$1\frac{1}{4}$	500	273	...
Virginia City, Neb..	" 1875......	2	$1\frac{1}{4}$	100	315	...
Wapakoneta, O......	March, 1873....	3	$1\frac{3}{16}$	150	265	...
" "	" "	3	$1\frac{1}{8}$	1250	244	...
Macon, Ga...........	Feb., 1873.......	4	$1\frac{1}{8}$	100	267	...
Esconawba, Mich...	June, 1873......	4	$1\frac{1}{8}$	1000	223	...
Appleton, Wis.......	" "	4	$1\frac{1}{8}$	150	267	...
" "	" "	4	$1\frac{1}{8}$	1000	227	...
Huntington, Ind.....	March, 1874....	4	$1\frac{1}{8}$	1000	202	...

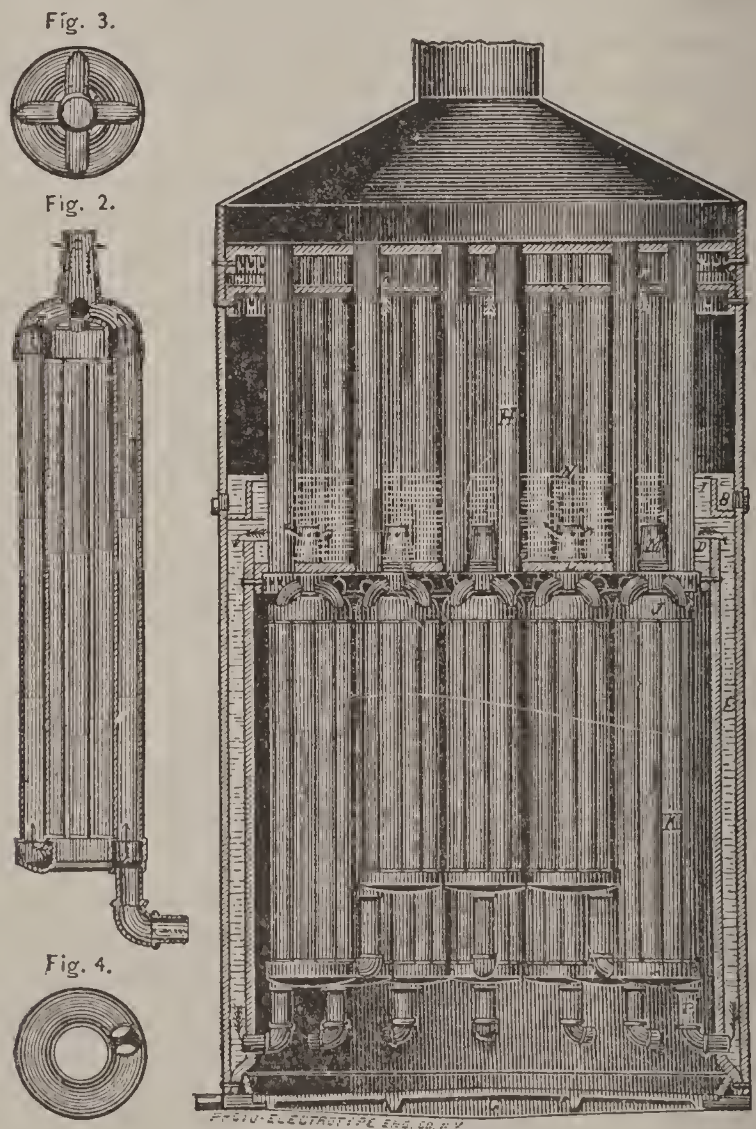
PERPENDICULAR HEIGHTS THROWN BY MODERN STEAM FIRE-ENGINES.

Location.	Date.	No. of Streams.	Size of Nozzle.	Feet of Hose.	Height in Feet.
THE SILSBY.					
Stratford, Ont	March 1st, 1875	1	$1\frac{1}{8}$	1000	200
Charlottetown, P. E. I	Nov. 25th, 1875	1	1	1000	197
Allentown, Pa	Sept. 30th, 1872	1	$1\frac{1}{4}$	350	180
Philadelphia	1881	1	...	......	225
THE AMOSKEAG.					
Albany, N. Y	Sept. 4th, 1867	1	$1\frac{1}{4}$	300	220
Harrisburg, Pa	Sept. 2d, 1867	1	$1\frac{1}{8}$	50	217
Albany, N. Y	June 26th, 1871	1	1	100	205
THE CLAPP & JONES.					
Lebanon, Pa	Nov. 1872	1	$1\frac{1}{8}$	500	229
Newton, N. J	Oct. 1873	1	$1\frac{1}{15}$	200	228
Reading, Pa	Nov. 1872	1	$1\frac{1}{16}$	100	202
THE GOULD.					
Burlington, Vt		1	$1\frac{1}{4}$	100	185
LA FRANCE.					
Petersburg, Va	Jan. 20th, 1887	1	$1\frac{3}{8}$	......	170
Chester, Pa	Oct. 13th, 1887	1	$1\frac{1}{2}$	.. ...	205
Baltimore, Md	Jan. 16th, 1889	1	...	......	247
THE BUTTON.					
Cohoes	Aug. 1867	1	$1\frac{1}{4}$	100	267
Cohoes	Aug. 1867	2	1	110	210
Marietta, O	March, 1875	1	$1\frac{1}{8}$	1650	165
AHRENS.					
St. Louis	Aug. 9th, 1873	1	$1\frac{3}{8}$	200	197
Indianapolis	Feb. 7th, 1876	1	$1\frac{1}{2}$	100	235
Indianapolis	Feb. 7th, 1876	2	$1\frac{1}{8}$	100	200

*A steam fire-engine, if well proportioned and in good order, will throw a vertical stream about ⅔ the distance that it is capable of throwing one horizontally, provided the air is perfectly calm and light.

THE La FRANCE STEAM FIRE-ENGINES.

The La France Fire-Engines are both of the rotary and piston types. The company commenced building the rotary fire engines in 1874, but subsequently recognizing the demand for piston engines, decided to put into the market an engine that would meet all requirements, and if possible out-steam and out-water pressure all other competitors.



La FRANCE BOILER.

The chief features of their rotary fire engine are the following: The engine cams are five armed, and are provided with packing plates which are forced by the steam against the heads, keeping these perfectly steam tight and allowing for expansion and wear. Packing strips

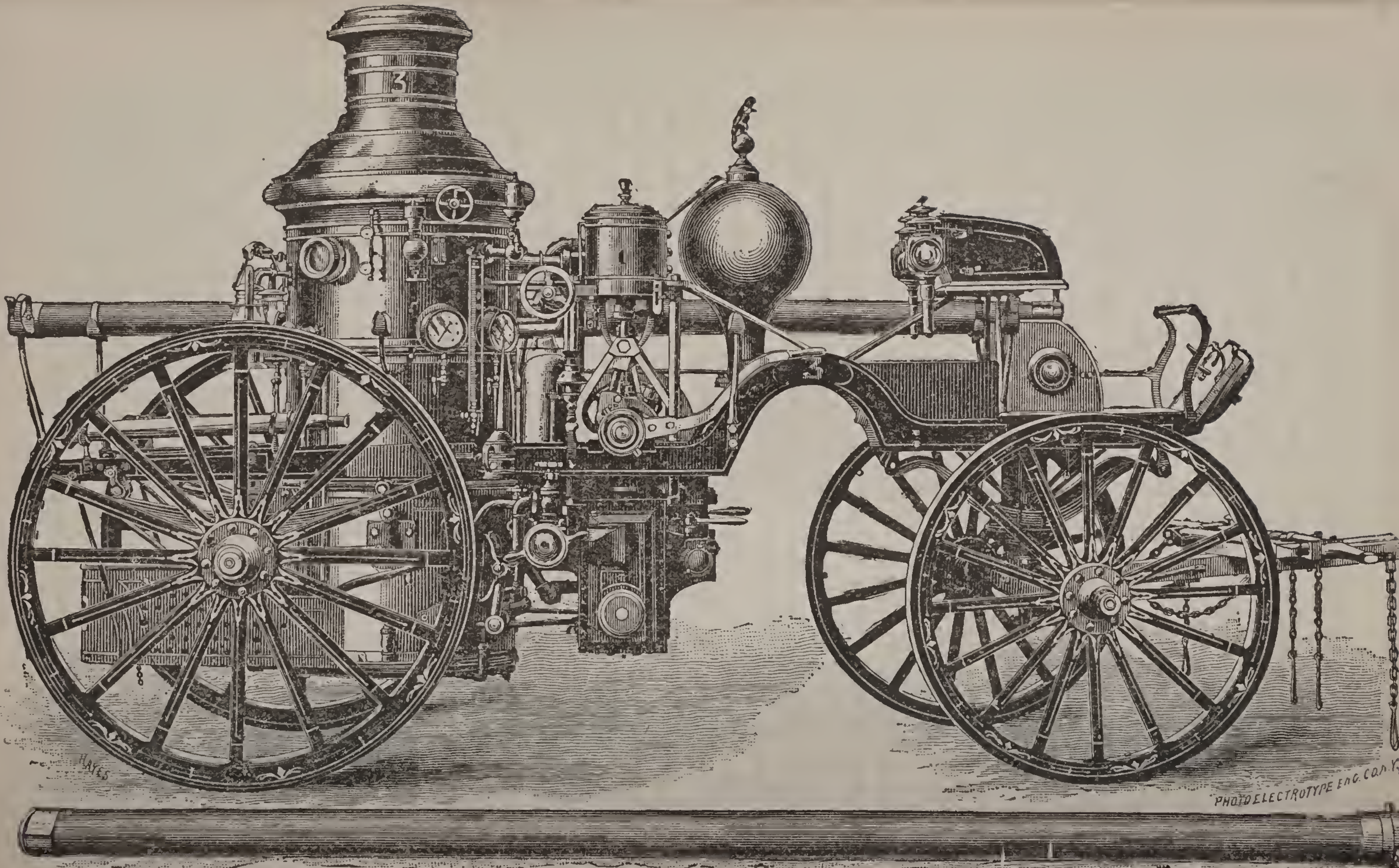
are also placed in the ends of the arms to keep the cams tight. The pump cams have six arms, each packed and bearing on the case. The sides of the case are provided with removable plates, upon which most of the wear comes; these plates are counter-bored at the bottom to prevent the cams from "pounding," when doing heavy work. They may be depended upon for years, but if cut by hard usage, can be renewed cheaply, thereby saving the case.

To supply the demand for steam made by the rotary engine, the La France boiler (see cut) is especially adapted; and it has a record for quick steaming and for holding the pressures whenever desired.

In this boiler the crown sheet, L, is placed three inches below the top of the fire-box sheet, as shown at D. The "water nests" are suspended in the fire-box, as at K. The top "header," J, is screwed through the crown-sheet, and so arranged that the lateral discharge openings are three inches above the crown-sheet at M. The bottom "water rings" are each connected with the bottom of the boiler by means of nipples and elbows, as shown at F. By this arrangement a great extent of water surface is exposed to the heat without obstructing the smoke-flues or weakening the crown-sheet with numerous openings.

The smoke-flues, H, are arranged to encircle the "nest headers," making a direct draught for the flue through the nest: They pass directly through the boiler to the stack above, passing near the top of the boiler through the diaphragm sheet, A. The openings in the sheet are slightly larger than the smoke-flues, leaving an annular space through which the steam passes to the space above, which serves as a steam drain, from whence the steam-pipe carries it to the engine. This causes the steam to pass in films in contact with the hot flues, at once superheating the steam and keeping the tops of the flues in the moisture, preventing burning and leaking.

Above the crown-sheet a ring, I, of L-shaped cross section, is attached to the inner surface of the boiler shell, forming a receptacle, B, for mud and other impurities in the water, which are carried upward by the natural circulation of the water, and which in boilers of ordinary



THE La FRANCE IMPROVED PISTON-ENGINE

construction find their way to the water-leg and drop tubes, working destruction to the boiler. Mud-plugs are provided for cleaning and washing the space B.

The circulation, as shown by the arrows, is down the "leg," E, and through the "nests," K, discharging steam and water laterally from the openings over the crown-sheet, I. By this means the crown-sheet is always protected by a pan of water formed by the extended edges of the fire-box sheet, D, and cannot be injured, whether the water line is carried above or below the sheet, so long as enough water remains in the leg, E, to supply the "nests."

The circulation down the "leg" and through the "nests" is so violent that no sediment can lodge in them.

On account of the nest tubes being connected both to the crown-sheet and water-leg, the water in the boiler, when attached to a heater, is kept at a uniform temperature throughout, as the circulation of water is continuous through the nest of tubes and water-leg. This is not the case in the ordinary drop-tube boilers, as their drop tubes, hanging down in the fire-box have plugs welded in the ends, and there can be no circulation until a fire is started under them. These drop tubes have only one opening which is screwed into the crown sheet, thus compelling both supply and discharge of water to take place at the same end of the tube.

It has long been a demonstrated fact that the old drop-tube boiler, when connected to a heater, has only the benefit of having the small amount of water on the crown-sheet and in the water-leg heated, leaving the drop tubes, the principal heating surface, almost cold.

The boiler is fed through an opening under the fire-box door, which prevents the collecting of scale or mud under the door ring, and also avoids the nuisance of a leaky fire-box door. The boiler is supplied with a dump-grate, G, provided with a sloping flange, shown in the engraving, which protects the bottom rivets from the intense heat of the furnace. The fire is governed by a variable exhaust; and a pop valve is supplied, so arranged that it can be blown off at any pressure below the point set without disturbing the adjustment of the spring.

The La France Improved Piston Engine (see cut) is supplied with this same boiler; the steam and water cylinders being set at a short distance from, and not bolted to it, thus providing against differential expansion between boiler, engine and pump.

The steam-pipes are short and closely coupled between boiler and cylinders, to prevent condensation, and in case of leakage are easily and quickly repacked, five minutes sufficing for the operation. The pump is of the vertical duplex type.

The piston and pump rods are rigidly fastened together by a yoke, the whole being in but two pieces. Within this yoke plays a pitman, which connects it with the crank shaft.

This arrangement runs quietly and almost without friction, doing away with the troublesome link boxes and slides, which heat and bind when engines are run at high pressures.

The packing in the pump barrels is so constructed, that if the leather cups give way the pumps will not be disabled. The pumps have large water ways and the valves are so arranged, as to enable the pump pistons to be driven at a high speed to meet the demand for an increase of water without recourse to a larger engine. The pump head is hung from the frame by four hangers, and from it stand four posts to which is bolted the steam cylinder head. This enables any ordinary engineer to take apart pump and engine, and replace them without getting them out of line; and they will come to their centers without trouble or loss of time.

These engines are especially adapted to heavy and wearing work, high draught, and long distance throws.

The La France Fire Engines are to be found in the best organized departments of the country, viz: New

York, Buffalo, Brooklyn, Philadelphia, Baltimore, Minneapolis, San Francisco, Savannah, Wilmington, etc. They are the result of the inventive genius of Mr. T. S. La France, whose name they bear.

HIGH-PRESSURE OR NON-CONDENSING STEAM-ENGINES, FIRE, LOCOMOTIVE, AND STATIONARY.

High-pressure or non-condensing engines are those engines in which the steam, after its action on the piston, is permitted to escape into the atmosphere, and in which, therefore, the pressure of the outgoing steam must exceed the atmospheric pressure of 15 pounds to the square inch. All steam fire-engines, locomotives, and nearly all stationary engines, belong to this class.

If steam at 30 pounds to the square inch above atmospheric pressure, that is to say, 30 pounds on the steam-gauge, be applied to the piston of a high-pressure engine, it will exert a force equal to the pressure in the boiler above the atmosphere, providing there be sufficient room for the steam, and no obstacle to impede its free flow or lessen its pressure between the boiler and the cylinder, the other side of the piston being open to the atmosphere. The steam having to overcome the atmospheric pressure in its escape from the cylinder, 15 pounds from the total pressure of 45 pounds will be lost.

Advantages of the High-pressure Engine.— The principal advantages of the high-pressure engine are, its lightness, moderate first cost, economy of space, and the facilities it affords for an increase of pressure and speed, should it become necessary; hence, the high-pressure engine being lighter, more simple, compact, and less expensive in construction, and also less complicated, requiring less skill to manage and less cost to repair, is more

desirable for stationary, land, and river-boat purposes than the low-pressure engine.

The high-pressure engine is also desirable in marine steamers on account of economy of space, weight, etc., though objectionable in consequence of its greater consumption of fuel. The causes which occasion this extra consumption of fuel are, first, the steam lost in overcoming the pressure of the atmosphere; second, the loss of heat by radiation in consequence of high pressures and high temperatures; third, the loss occasioned by the escape of heat through the chimney.

In the high-pressure engine, pressure and speed can be increased to any limit within the bounds of safety. Not so, however, in the case of the low-pressure, as, with extremely high pressures and correspondingly high temperatures, it would be impossible to condense the steam, and the result would be a loss of power, occasioned by back pressure.

POWER OF THE STEAM-ENGINE.

The power which a steam-engine can furnish is generally expressed in "horse-power." It will, therefore, be of interest to engineers, and of special value to many, to have briefly stated what is meant by a "horse-power," and how it has happened that the power of a steam-engine is thus expressed in reference to that of horses. Prior to the introduction of the steam-engine, horses were very generally used to furnish power to perform various kinds of work, and especially the work of pumping water out of mines, raising coal, etc. For such purposes, several horses working together were required. Thus, to work the pumps of a certain mine, five, six, seven, or even twenty-five horses were found necessary. When it was proposed to substitute the new power of steam, the proposal natu-

rally took the form of furnishing a steam-engine capable of doing the work of the number of horses used at the same time. Hence, naturally followed the usage of stating the number of horses which a particular engine was equal to, that is, its "horse-power." But as the two powers were only alike in their equal capacity to do the same work, it became necessary to refer in both powers to some work of a similar character which could be made the basis of comparison. Of this character was the work of raising a weight perpendicularly. A certain number of horses could raise a certain weight, as of coal out of a mine, at a certain speed; a steam-engine, of certain dimensions and supply of steam, could raise the same weight at the same speed. Thus, the weight raised at a known speed could be made the common measure of the two powers. To use this common measure, it was necessary to know what was the power of one horse in raising a weight at a known speed.

By observation and experiment it was ascertained that, referring to the average of horses, the most advantageous speed for work was at the rate of two-and-a-half miles per hour; that, at that rate, he could work eight hours per day, raising perpendicularly from 100 to 150 pounds. The higher of these weights was taken by Watt, that is, 150 pounds at $2\frac{1}{2}$ miles per hour. But this fact can be expressed in another form: $2\frac{1}{2}$ miles per hour is 220 feet per minute $\left(\frac{2\frac{1}{2} \times 5280}{60} = 220\right)$. So, the power of a horse was taken at 150 pounds, raised perpendicularly, at the rate of 220 feet per minute. This also can be expressed in another form: The same power which will raise 150 pounds 220 feet high each minute, will raise

300	pounds	110 feet	high	each	minute.
3,000	"	11 "	"	"	"
33,000	"	1 foot	"	"	"

Thus, in each case, the total work done is the same as the same number of pounds is raised one foot in one minute.

It will be clearly perceived that 33,000 pounds, raised at the rate of one foot high in a minute, is the equivalent of 150 pounds at the rate of 220 feet per minute (or $2\frac{1}{2}$ miles per hour), and it will necessarily follow that 33,000 pounds, raised at the rate of one foot per minute, expresses the power of one horse, and has been taken as the standard measure of power. It has thus happened that the mode of designating the power of a steam-engine has been by "horse-power," and that one horse-power, expressed in pounds raised, is a power that raises 33,000 pounds one foot each minute. This unit of power is now universally received. Having a horse-power expressed in pounds raised, it was easy to state the power of a steam-engine in horse-power, which was done in the following manner:

The force with which steam acts is usually expressed in its pressure in pounds on each square inch. The piston of a high-pressure steam-engine is under the action of the pressure of steam from the boiler, on one side of the piston, and under the back action of the pressure due to the discharging steam, on the other side. The difference between the two pressures is the effective pressure on the piston; and the power developed by the motion of the piston, under this pressure, will be according to the number of square inches acted on and the speed per minute with which the piston is assumed to move.

Thus, let the number of square inches on the surface of the piston of a steam-engine be 100, the *effective* pressure on each square inch be 33 pounds, and the movement of the piston be at the rate of 200 feet per minute, then the total effective pressure on the piston will be $100 \times 33 = 3300$ pounds, and the movement being 200 feet per minute, the piston will move with a power equal to raising

660,000 pounds one foot high each minute, (as $3300 \times 200 = 660,000$,) and as each 33,000 pounds raised one foot high is one-horse power, and $\frac{660,000}{33,000}$ is 20, then the power of this engine is 20-horse-power. If this power is used to do work, a part of it will be expended in overcoming the friction of the parts of the engine and of the machinery through which the power is transmitted to perform the work. The calculation made refers to the total power developed by the movement of the piston under the pressure of steam.

The number of feet moved over by the piston each minute is known from the length of stroke of the piston in feet, and the number of revolutions of the engine per minute, there being two strokes of the piston for each revolution of the engine. When these three facts are known, the power of an engine can be readily and accurately ascertained; and it is evident that, without the knowledge of each of these facts, viz., square inches of piston, effective pressure on each square inch, and movement of piston per minute, the power cannot be known. But circumstances, especially those existing when the condensing-engine was introduced by Watt, led to assumptions as to pressure per square inch and speed of piston which, though true at the time, have long since ceased to be true, and consequently the rules based on such assumptions are entirely inapplicable, and when used must of necessity give false results.

With regard to how much is understood by a horse-power, there is in this country no question at all. Horses vary in their ability to endure protracted labor, and our standard may be more or less than what an average horse is able to do; but that is of little importance. So long as the number of horse-power of an engine conveys a definite knowledge of its power, it is of little consequence what

relation it sustains to the action of any particular class of animals.

FOREIGN TERMS AND UNITS FOR HORSE-POWER.

Countries.	Terms.	Eng. translation.	Units.	English equivalent.
English.	Horse-power.	Horse-power.	550 foot-pounds.	550 foot-pounds.
French.	Force de cheval.	Force-horse.	75 kilogr. metres	542.47 foot-pounds.
German.	Pferde-krafte.	Horse-force.	513 Fuss-funde.	582.25 foot-pounds.
Swedish.	Hast-kraft.	Horse-force.	600 Skalpund-fot	542.06 foot-pounds.
Russian.	Syl-lochad.	Force-horse.	550 Fyt-funt.	550 foot-pounds.

The French apply the term force de cheval to a power capable of raising 4.5000 kilogrammes 1 metre high in 1 minute, which is equal to a force capable of raising 32,549 pounds 1 foot high in a minute, which is about $\frac{1}{73}$ less than our unit of measure.

Horse-power.	Force de cheval.	Horse-power.	Force de cheval.
10	10.14	60	60.83
15	15.20	65	65.89
20	20.28	70	70.97
25	25.34	75	76.03
30	30.41	80	81.11
35	35.48	85	86.17
40	40.55	90	91.25
45	45.62	95	96.31
50	50.69	100	101.3856
55	55.75		

In this country, and also in England, it has been usual to assign a certain horse-power for a high-pressure engine of certain dimensions; thus, an engine having a cylinder 10 inches in diameter and 24 inch stroke of piston would be called a 25-horse-power engine, and so on with high-pressure engines of all dimensions. But it is utterly im-

possible to say of what horse-power an engine of the above dimensions would be, unless we knew the effective pressure to be exerted against the piston, and also the speed at which the piston is intended to move.

There are several kinds of horse-power referred to in connection with the steam-engine,— the "nominal," "indicated," "actual or net," "dynamometrical," and "commercial."

The nominal horse-power is admitted to be a force capable of raising a weight of 33,000 pounds one foot high in one minute, or 150 pounds 220 feet high in the same length of time. The term "*nominal horse-power*," as before stated, originated at the time of the discovery of the steam-engine, from the necessity which then arose for comparing its powers with those of the prevailing motor. The *nominal horse-power* was based on the general principle of the age, which dealt with low pressures and slow piston speeds. These quantities have of late years been greatly increased, and the old formula, in consequence, has become of less importance as a true expression of relative capacity. Hence, the term *nominal horse-power* is in reality of itself nominal, as Watt, in order to have his engines give satisfaction, added some twenty-five per cent. to the real work of the best horses in Cornwall.

But the term nominal horse-power implies the ability to do so much work in a certain period of time; and, in order to have a proper idea of it, a unit of measure is also employed. This unit is called a horse-power, and, as before stated, is equal to 33,000 pounds raised through a space of one foot in one minute: it is the execution of 33,000 foot-pounds of work in one minute. Work is performed when a pressure is exerted upon a body, and the body is thereby moved through space. The unit of pressure is one pound, the unit of space one foot, and work is

measured by a "foot-pound" as a unit. Thus, if a pressure of so many pounds be exerted through a space of so many feet, the number of pounds is multiplied into the number of feet, and the product is the number of foot-pounds of work; hence, if the stroke of a steam-engine be seven feet, and the pressure on each square inch of the piston be 22 pounds, the work done at each single stroke, for each square inch of the piston, will be 7 multiplied by 22, equal to 154 foot-pounds.

Indicated Horse-power.—The indicated horse-power is obtained by multiplying together the mean effective pressure in the cylinder in pounds per square inch, the area of the piston in square inches, and the speed of the piston in feet per minute, and dividing the product by 33,000; and as the effective pressure on the piston is measured by an instrument called the indicator, the power calculated therefrom is called the *indicated* horse-power.

Actual or Net Horse-power.—The actual or net horse-power expresses the total available power of an engine; hence it equals the indicated horse-power minus the amount expended in overcoming the friction. The latter has two components, viz., the power required to run the engine, detached from its load, at the normal speed, and that required when it is connected with its load. For instance, if an engine is desired to drive 10 machines, each requiring 10-horse power, it should be of sufficient size to furnish 100 *net horse-power;* but to produce this would require about 115 or 120 indicated horse-power. The net horse-power of an engine may be determined by subtracting from the indicated horse-power the power required to overcome the friction of the engine when in the regular performance of its duty.

Dynamometrical Horse-power.—The dynamometrical horse-power is the net power of the engine after allowing

for friction, etc., and this alone is the power with which those who use steam-engines are concerned. Though not equal in point of accuracy to the indicator, the dynamometer gives the actual power of small engines near enough for all practical purposes; but it cannot be conveniently applied to large engines.

Commercial Horse-power. — The term commercial horse-power is not generally used, and, when used, has no definite meaning, as there is no recognized standard in use among engineers and manufacturers by which to buy and sell engines. Though the question has often been discussed, and its importance generally recognized, it has never been universally adopted, consequently, the nominal horse-power of a steam-engine means anything that the manufacturer feels disposed to call it. It seems very strange that this should be so, as every civilized country has its standard of weights and measures, with strict laws compelling the observance of these standards in the various operations of trade. The public, also, are keenly alive to the importance of these regulations, and no purchaser is so unmindful of his own interests as not to insist on obtaining the full weight of most articles for which he pays; but steam-engines are almost universally bought and sold by a system of guess-work which would not for a moment be tolerated, were it attempted to be practised in any other branch of trade. There is great need of some recognized standard that would designate the number of square inches in the cylinder, travel of piston in feet per minute, and average steam pressure through the length of the stroke, that should constitute the commercial horse-power of engines, say, for instance, 4 square inches in the cylinder, a piston speed of 240 feet per minute, and an average pressure of 40 pounds per square inch; such proportions would be capable of developing a horse-power

in most ordinary high-pressure engines, without the necessity of excessive speed or undue straining.

Small engines are generally more economical than large ones, where the steam pressures, points of cut-off, and power developed are the same; as, although the smaller engine, at the same speed, would be less economical at the higher speed necessary to produce the same power, the gain due to high speed overbalances the loss due to the smaller size of the cylinder.

Engines too large for the work to be done are less economical than if proportionate to the power required; for instance, an engine of 40-horse power doing the work of 20-horse power, and running at a high speed, the steam would necessarily have to be throttled down by the governor from, say, 60 or 70 pounds boiler pressure to 25 or 30 pounds on the piston, involving a loss of nearly $\frac{3}{5}$ in fuel, as the loss by atmospheric pressure in non-condensing engines is equally as much for 25 pounds as for 100 pounds pressure.

The steam necessary to drive a 40-horse power high-pressure engine with *no load*, would give more than 10-horse power in a small engine. The cylinder of any engine should be of sufficient size to give the full power required, leaving a reasonable margin for variation in pressure, and for recuperative power under sudden increase of load, *and no larger.* Large engines doing the work easily, and at a low pressure, are economical only when the speed is reduced in proportion to the work to be done.

There are three conditions which influence the economy of non-condensing steam-engines: *steam pressure, expansion,* and *speed of piston;* for it will be found, on selecting any particular *horse-power*, that the highest steam pressures and revolutions and the shortest points of cut-off are

those which show the greatest economy of steam. When these three conditions are all favorable at the same time, the maximum economy is obtained; but when only one or two of these conditions are favorable, the results are so modified as often to appear contradictory.

Effective Pressure against the Piston.—The character of the connections between the boiler and cylinder, their length, degree of protection, number of bends, shape of valves, etc., must all be considered in forming an estimate of the initial steam pressure on the cylinder; while the effective pressure will depend upon the point at which the steam is cut off, and the freedom with which it exhausts; as it has been fully demonstrated by experience that the effective pressure against the piston in the cylinder of steam-engines, more particularly slide-valve engines, rarely, if ever, exceeds $\frac{2}{3}$ of the boiler pressure, as the free flow of the steam from the boiler to the cylinder is obstructed by the action of the governor and affected by the character of the connection, as before stated, so that in calculating the horse-power of steam-engines, not more than $\frac{2}{3}$ of the boiler pressure should be taken as the effective pressure in the cylinder.

In comparing the relative merits of different engines, it is of more importance to steam users to look at the actual power which an engine is capable of exerting, rather than at the stated nominal horse-power or size of cylinder; as it is no uncommon thing, with two engines of the same diameter of cylinder and the same general proportions, for one to be capable of developing much more power than the other, even with a less consumption of coal per actual horse-power.

The nominal horse-power of a high-pressure engine, though never very definitely defined, should obviously hold the same relation to the actual power as that which

obtains in the case of condensing engines, so that an engine of a given nominal power may be capable of performing the same work, whether high pressure or condensing. But whether it does or not, the standard of a horse-power serves as a standard of comparison, and its utility as a unit of reference is not impaired, whether it represents the actual power of one horse or three, so long as the standard is universal. The following rule will be found very convenient for those who may have occasion to estimate the horse-power of high-pressure or non-condensing steam-engines, as it is practical and correct.

Rule for finding the Horse-power of Steam-engines.—Multiply the area of the piston by the average steam pressure per square inch; multiply this product by the travel of piston in feet per minute; divide this product by 33,000, and the quotient will be the horse-power.

EXAMPLE I.

Diameter of cylinder in inches..................	10	
	10	
Square of diameter of cylinder................	100	
Multiplied by the decimal......................	.7854	
Area of piston..	78.54	inches.
Boiler pressure, 60 pounds; cut-off, ½ stroke, Average pressure in cylinder, 50 pounds;* 5 off for loss by condensation, etc.,	45 lbs.	
	39270	
	31416	
	3534.30	
Travel of piston in feet per minute†..........	250	
Divide by..	33,000)883575.00	
	26.	horse-power.

* See Tables of Average Pressure, pages 336, 337.

† *To find the Travel of Piston in Feet per Minute.*—Multiply the distance travelled for one stroke in inches by the whole number of strokes in inches, and divide by 12. See Tables on pages 177 and 178.

EXAMPLE II.

Diameter of cylinder in inches......................	10
	10
Square diameter of cylinder........................	100
Multiplied by....................................	.7854
Area of piston..	78.54 inches.
Boiler pressure, 80 pounds; cut-off, ¼ stroke, Average pressure in cylinder, 47¾ pounds; 5 off for loss by condensation, etc.,	42.75 lbs.
	39270
	54978
	15708
	31416
	3357.5850
Travel of piston in feet per minute,	300
Divided by.........	33,000)1007275.5000
	30.* horse-power.

EXAMPLE III.

Diameter of cylinder in inches.......................	20
	20
Square of diameter of cylinder....................	400
Multiplied by...	.7854
Area of piston..	314.1600
Boiler pressure, 60 pounds; cut-off, ¾ stroke, Average pressure in cylinder, 57 pounds; 5 off for loss by condensation, etc.,	52 lbs.
	6283200
	15708000
	16336.3200
Travel of piston in feet per minute,	300
Divided by..............................	33,000)4900896.0000
	148.* horse-power.

* In these examples, the fractional parts of a horse-power have been intentionally left out.

EXAMPLE IV.

Diameter of cylinder in inches....................	20
	20
Square of diameter of cylinder.....................	400
Multiplied by..	.7854
Area of piston..	314.1600 inches.
Boiler pressure, 85 pounds; cut-off, ¼ stroke, Average pressure in cylinder, 50 pounds; 5 off for loss by condensation, etc.,	45 lbs.
	15708000
	12566400
	14137.2000
Travel of piston in feet per minute............	350
	7068600000
	424116000
Divided by................................ 33,000)	4948020.0000
	149. horse-power.

It will be seen from the foregoing examples, that any increase of pressure and piston speed makes a very perceptible difference in the power of the engine; but this augmentation of power is not obtained without an increased quantity of steam in proportion to the increased pressure and speed, except where the steam is expanded to its lowest available limits.

A high-pressure engine, for instance, working with 40 pounds of steam above the atmospheric pressure upon the piston, cut off at one-third, and expanding the remainder of the stroke, the piston travelling 220 feet per minute, would only exert the power for which it was nominally calculated, independent of friction; but take the same engine, and increase the speed from 220 to 440 feet per minute,— which is quite practicable,— the power of that engine would then be doubled, less the extra friction; but double the quantity of steam would have been used.

Suppose steam at 80 pounds pressure was introduced to the same cylinder, cut off at one-third and worked expansively, as in the first case, the power given out by the 80 pounds pressure would be less in proportion than that at 40 pounds, as the exhaust would be thrown away at about five times the pressure that it was at 40 pounds, and a portion of the useful effect of the steam would be lost, in consequence of its not being expanded to its full limit, the lost portion escaping into the atmosphere and exerting a corresponding back pressure on the piston.

The following method will be found very convenient, as it somewhat abbreviates the rule used in the foregoing examples for calculating the horse-power of a steam-engine.

TABLE OF FACTORS.

Diameter of Cylinder in Inches.	Factor.	Diameter of Cylinder in Inches.	Factor.
8	.152	26	1.608
10	.238	30	2.142
12	.342	36	3.084
14	.466	40	3.808
16	.609	45	4.82
18	.771	48	5.483
20	.952	50	5.95
22	1.151	56	7.463
24	1.37	60	8.568

Rule.— Multiply the factor of the given diameter of cylinder by the speed of piston in feet per minute (using all below hundreds as decimals); multiply this product by the average pressure in pounds per square inch. This last product will be the horse-power of the engine.

EXAMPLE.

Diameter of cylinder, 12 inches,	.342
	2.40
Travel of piston per minute, 240 feet,	13680
	684
Average pressure, 42 pounds,	.82080
	42
	164160
	328320
	34.47360 horse-power.

Rule for finding the Horse-power of a Steam Fire-Engine.—Multiply the area of piston by the steam-pressure in pounds per sq. in. Multiply this product by the travel of the piston in feet per minute. Divide this product by 33,000, and .7 of the quotient will be the horse-power of the engine.

EXAMPLE.

Area of piston.........................50.2656 sq. in.
Steam pressure.........................80 lbs. per sq. in.*
Travel of piston.......................200 feet per minute.

```
            50.2656
                 80
           --------
          4021.2480
                200
          ---------
33,000)804249.6000(24.37
       66000        2.437
       -----            7
       144249      ------
       132000      17.059 horse-power.
       ------
        122496
         99000
        ------
         234960
         231000
         ------
           3960
```

* In estimating the power of steam fire-engines, the pressure should be taken at from 10 to 15 lbs. per sq. in. less than that indicated by the gauge, as the average pressure in the cylinders is generally from 10 to 15 lbs. per sq. in. less than the boiler pressure.

THE POWER OR HORSE-POWER OF THE LOCOMOTIVE.

In estimating the power of a locomotive, the term horse-power is not generally used, as the difference between a stationary steam-engine and a locomotive is such that, while the stationary engine raises its load, or overcomes any directly opposing resistance with an effect due to its capacity of cylinder, the load of a locomotive is drawn, and its resistance must be adapted to the simple adhesion of the engine, which is the measure of friction between the tires of the driving-wheels and the surface of the rails.

The power of the locomotive is measured in the moving force at the tread of the tires, which is called the traction force, and is equivalent to the load the locomotive could raise out of a pit by means of a rope passing over a pulley and attached to the circumference of the tire of one of the driving-wheels.

The adhesive power of a locomotive is the power of the engine derived from the weight on its driving-wheels, and their friction or adhesion on the rails. But the adhesion varies with the weight on the drivers and the state of the rails.

The tractive force of a locomotive is the power of the engine, derived from the pressure of steam on the piston, applied to the crank and the radius of the wheels.

Rule for finding the Horse-power of a Locomotive.—Multiply the area of the piston by the pressure per square inch, which should be taken as $\frac{2}{3}$ the boiler pressure; multiply this product by the number of revolutions per minute; multiply this by twice the length of stroke in feet or inches;* multiply this product by 2, and divide by 33,000; the result will be the power of the locomotive.

* If in inches, divide by 12.

EXAMPLE.

Cylinder, 19 inches.
Stroke, 24 "
Diameter of drivers, 54 inches.
Running speed, 20 miles per hour.
Area of piston, 283.5 square inches.
Boiler pressure, 130 pounds per square inch.
Maximum pressure in cylinders, 80 pounds.

$$\frac{283.5 \times 80 \times 4 \times 124 \times 2}{33,000} = 681.6 \text{ horse-power.}$$

Rules for Calculating the Tractive Power of Locomotives.

Rule I.— Multiply the diameter of the cylinder in inches by itself; multiply the product by the mean pressure of steam in the cylinder in pounds per square inch; multiply this product by the length of stroke in inches; divide the product by the diameter of the wheels in inches. The result equals the tractive force at the rails.

Rule 2. — *To calculate the load which can be hauled by an engine on a level at a given speed.*—Divide the tractive force, as per Rule 1, by the resistance in pounds per ton due to friction, imperfection of road, and winds. The quotient is the total load in tons, comprising the engine, tender, and train.

Rule 3.—*To calculate the total resistance of engine, tender, and train at a given speed, due to friction, etc.* —Square the speed in miles per hour, divide it by 171, and add 8 to the quotient. The result is the total resistance at the rails in pounds per ton weight.

Rule 4.—*To find the load a locomotive can haul at a given speed on a given incline.*— Divide the tractive power of the engine in pounds by the resistance due to gravity on a given incline, added to resistance due to assumed

velocity of train in pounds per ton; the quotient, less the weight of the engine and tender, equals the load in tons which the engine can haul on a given incline.

Example, Rule I.—What is the tractive force of a locomotive 16 inch cylinder, 24 inch stroke, 4 feet drivers, mean pressure 80 pounds per square inch?

Cylinder, 16 inches...... 16
16
―――
96
16
―――
256
Pressure in pounds, 80.. 80
―――
20480
Stroke, 24 inches......... 24
―――
81920
40960
―――
Drivers, 4 ft. or 48 in... 48)491520
―――
10240 lbs. tractive force.
2000)10240 lbs. tractive force.
―――
$5\frac{3}{25}$ tons.

Example, Rule 2.—What load can a locomotive, 16 inch cylinder, 24 inch stroke, 4 feet drivers, mean pressure 80 pounds, haul on a level at 30 miles per hour?

Tractive force, obtained as in Rule 1, is 10240 lbs.

Velocity per hour, 30 miles.

30
30
―――
171)900
―――
Resistance in 5.26
lbs. per ton......... 8
―――
13.26

13.26)10240
―――
$772\frac{1}{4}$ load in tons.

Example, Rule 3.—What load can a locomotive, 16 inch cylinder, 24 inch stroke, 4 feet drivers, mean pressure 80 pounds, haul on a grade of 40 feet to the mile at 30 miles per hour?

Tractive force, obtained as in Rule 1.....	10240 lbs.
Resistance, in lbs. per ton, due to gravity (see Table of Gradients)............	56
Resistance, in lbs. per ton, due to friction, winds, etc............................	13.26
Total resistance in lbs. per ton...........	69.26
Tractive force divided by total resistance equals load, in tons, engine can haul, less engine and tender....	69.26)10240.00 .... 147.83
Weight of engine and tender in tons.....	55.65
Load in tons..	92.18

TABLE OF GRADIENTS.

RISE IN FEET PER MILE AND RESISTANCE DUE TO GRAVITY ALONE.

	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Gradient of 1 inch...........	20	25	30	35	40	45	50
Rise in feet per mile........	264	211	176	151	132	117	105
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Resistance in pounds per ton of train................	112	89½	74½	64	56	50	45

Resistance, due to gravity on any incline, in pounds per ton, of train, equals 2240 divided by rate of gradient.

EXAMPLE.

Gradient or rise of 1 inch in 20 feet.................2240 gross ton.

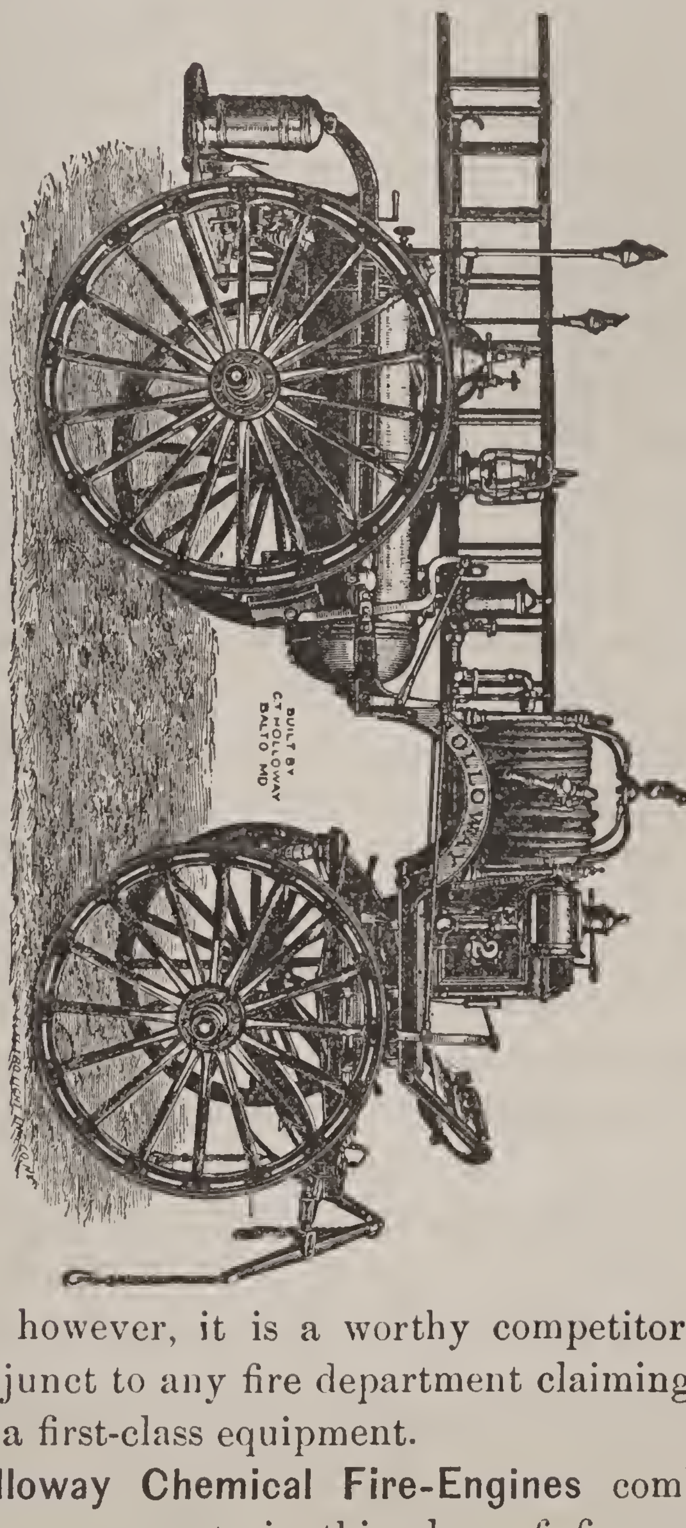
20)2240

Resistance in lbs. per ton........................ 112

The power of a locomotive may be roughly computed by calling it equal to $\frac{1}{6}$ of the weight on the driving-wheels, when the rails are wet or perfectly dry.

THE HOLLOWAY CHEMICAL FIRE-ENGINE.

The Holloway Chemical Fire-Engine, a description of which has been accorded a place here, is not in any sense to be classed a steam fire-engine. As a modern



THE HOLLOWAY CHEMICAL FIRE-ENGINE.

fire-engine, however, it is a worthy competitor and an essential adjunct to any fire department claiming the distinction of a first-class equipment.

The Holloway Chemical Fire-Engines combine all the latest improvements in this class of fire apparatus,

having patent air vessels, agitators extending entire length of the tanks, pressure gauges, automatic reels, acid holders, copper tanks, etc.

The No. 2 size (see cut) represents the large engine; it is fitted with two heavy polished copper tanks, having a capacity of 80 gallons each. Both tanks are connected by a patent air vessel, which, in turn, has a short, direct and ample attachment to the automatic reel, thus enabling this size engine to produce a continuous stream for any length of time by alternately using and charging the tanks, without in anywise detaching or moving the hose.

The air vessel connecting the tanks operates in like manner as the air vessel on a steam or hand engine, producing a steady, uniform flow of the solution through the hose.

In addition to the attachment with the automatic reel, the air vessel has also two independent outlets for hose connections, so that three streams, when necessary, can be had from this engine at the same time.

The engines in appearance are very attractive, and being well proportioned run easily. They can be quickly drawn by horse or hand to whatever point they may be needed for service.

In construction these fire-engines are simple, strong and durable; they are made of the best materials, with workmanship and finish unexcelled. The frame is of wrought iron, to which the tanks are securely bolted and braced one to the other, the whole sustained by oil tempered platform springs, coach-bed axles, and patent wheels with brass hub caps.

The hose gallery and spool, on which there is 200 feet of four-ply rubber hose, with brass hose pipes, are placed over the arch of the frame, and the acid chamber, a simple and durable device, positive in its action, is conveniently located

outside of the tank. The acid holder being made of glass, the acid will remain perfectly pure for any length of time, which insures instantaneous operation as soon as the tanks are charged—this is quickly done.

A pressure gauge registers the amount of gas generated within the tanks, and also enables the attendant to determine the rapidity with which the tank is being emptied.

THE VALUE OF CHEMICAL ENGINES.

Chemical Engines are coming into use largely in all first-class fire departments; their great efficiency is praised by all intelligent firemen. The great advantage in their use is promptness in getting to work—no delay of attaching to the hydrant, laying off four or five hundred feet of heavy hose, and in getting up steam, as in the case of steam fire-engines. They can be placed immediately in front of a fire; one man can ascend to the fifth or sixth story of a building with the hose ready to go to work, without danger of damaging the goods on the lower floors of the building; whereas on the arrival of a steam fire-engine, it has to be attached to the hydrant, a hose carriage lays off the hose to the fire, half a dozen men are required to drag it up to the fifth or sixth story, and they play an inch or an inch and a quarter stream of water, and damage as much, or more, property on the lower floors by water as does the fire, making the loss by water sometimes triple that by fire. By the use of Chemical Engines the destruction by water could be avoided in a great measure, and every appliance which by its use will decrease this destruction of property should be availed of; if the means at present employed for that purpose is as destructive as fire, other and better appliances should be adopted; by so doing the record of losses will be materially reduced.

THE PRINCIPLE ON WHICH THE CHEMICAL ENGINE EXTINGUISHES FIRE.

Carbonic Acid Gas is heavier than air. Fire is supported by oxygen and cannot burn a second without it. The contents of the Chemical Engine—a liquid gas many times more dense than air—shuts off the supply of oxygen and instantly smothers the fire. Fire cannot burn in an atmosphere containing five per cent. of Carbonic Acid Gas.

Until the invention of these machines, fires have been met by means *too slow, too late, and too cumbersome.*

The time occupied in sending for a common hand or steam engine, and getting it into working order, often proves fatal, and fires which have an insignificant beginning often end in the most fearful conflagrations.

It is a well known fact that about ninety per cent. of the actual fires that annually occur are discovered in incipient stages, and might be extinguished without material loss.

Water permeated with Carbonic Acid Gas is the most simple and powerful means known to science for destroying fire.

Always ready, powerful and prompt, these Engines are capable of being used at any time, and in any place, and thus subduing a fire at the moment of its discovery, even though it be of an alarming extent, and at the same time avoiding damage that would follow if water alone was used.

In cases where no water can be had the Chemical Engine is invaluable. Its unprecedented success has been obtained exclusively by its intrinsic merit, and the actual and valuable service it has constantly rendered.

Millions of dollars have been saved by it every year.

SELF-PROPELLING STEAM FIRE-ENGINES.

Although self-propelling steam fire-engines were among the first of this class of machines manufactured in this country, their use has been very limited up to the present time. This arose partly from their increased weight, their extra first cost, and the apprehended danger of running them at high speeds through crowded streets; but as they have been recently modified so that their first cost or weight does not exceed that of those drawn by horses, the prejudice that formerly existed against them is fast giving way. They are very desirable particularly in the suburbs of large cities, as, when rightly constructed, they are as safe and easily managed as those drawn by horses, while they are more powerful and efficient.

WASTE IN THE HIGH-PRESSURE OR NON-CONDENSING STEAM-ENGINE.

A pound of good coal, it is universally admitted, will liberate, during complete combustion, over 14,500 units of heat, each unit being equivalent to 772 foot-pounds. The mechanical equivalent of the heat developed by the combustion of a pound of coal is, therefore, say $14{,}500 \times 772 = 11{,}000{,}000$ foot-pounds. A horse-power is always assumed to be equal to 33,000 foot-pounds per minute, or 1,980,000 foot-pounds per hour.

Therefore, the combustion of each pound of coal per hour liberates heat enough to develop $11{,}000{,}000 \div 1{,}980{,}000 =$ say 5-horse power; and in a perfect steam-engine the consumption of coal would be at about the rate of one-fifth of a pound per hour for each horse-power developed.

The greatest economy yet obtained in the best high-pressure engines may be taken at from 3 to 4 pounds of

coal per indicated horse-power per hour; but for ordinary high-pressure engines in this country and in England a consumption of from 7 to 9 pounds is quite common. In good modern high-pressure steam-engines the useful effect obtained from the work stored up in the fuel may be thus calculated:

Lost through bad firing and incomplete combustion	10 per cent.
Carried off by draught through chimney	30 " "
Carried away in the exhaust steam	50 " "
Utilized in motive power (indicated)	10 " "
	100

The minor causes of loss in the steam-engine are radiation of heat from the boiler, steam-pipes, and cylinder, from leakage and condensation; but the principal loss arises from the escape of the steam into the atmosphere with only a small portion of its heat utilized; this of itself leads to a loss of from 40 to 60 per cent; a further loss of useful effect in the steam-engine ensues from a portion of the motive power actually developed being absorbed by friction, the useful power of the engine being frequently reduced by this cause by from 10 to 15 per cent.

The use of good material, good workmanship, thorough lubrication and cleanliness, it is true, go far to lessen the friction and increase the efficiency of steam-engines; as also the use of high-pressure steam, high rates of expansion, efficient feed-water heaters, non-conductors and steam-packing, are conducive to economy; but what is needed to render the steam-engine what it should be, is complete combustion of the fuel in the furnace, the transfer of all the heat generated to the water in the boiler, the passage of the steam through the engine without the loss of heat, except such as is converted into motive power, the transmission of the remaining heat in the exhaust steam to the

feed-water, and the absence of friction in its working parts. In consequence of the enormous waste incurred in the use of the steam-engine, numerous attempts have been made to supersede steam as a prime mover, but as yet without success, as there are certain difficulties connected with the employment of all other agents which have as yet proved insurmountable. In short, there is not at present on the horizon the faintest dawn of the appearance of any mode of generating force calculated to compete with, much less to supersede, the steam-engine.

Electro-magnetism, from which, at one time, so much was expected, is now thoroughly understood to be a far more costly mode of obtaining power than the combustion of coal. Heat, electricity, magnetism, chemical affinity, force, are all equivalent to each other, according to ratios which are fixed and unalterable. The atomic weight of carbon is 6; that of zinc, 32. One pound of carbon will develop more heat, and consequently more force, than 5 pounds of zinc; whilst, weight for weight, the cost of the former to the latter is as 1 to 50. Taking into consideration all the various sources of waste, experience has shown steam-power to be 90 times cheaper than man-power, 70 times cheaper than electro-motor power, and 10 times cheaper than horse-power.

The discovery of a new motor, even if such a thing should happen, would take a quarter of a century to replace the present arrangements; nay, even then it would be the duty of the engineer and the inventor to strive to improve the modes of employing the agent we now possess, and to inquire in what direction further progress in its economical application would lead.

That great improvements can and will be made in the economical working of the steam-engine, none can doubt, who have compared its theoretical capabilities with its present performances.

TABLE COMPARING DUTY OF MODERN HIGH GRADE ENGINES.

Type of Engine.	Temperature of Feed Water.	lbs. of Water evaporated per lb. of Cumberland Coal.	lbs. of Steam per I. H. P. per hour.	lbs. of Cumberland Coal used per I. H. P. per hour.	Cost of I. H. P. per hour supposing coal $6.00 per ton.
Non-Condensing......	210°	10.5	29.	2.75	$0.0073
Condensing.............	100°	9.4	20.	2.12	0.0056
Compound Jacketed.	100°	9.4	17.	1.81	0.0045

DIFFERENT PARTS OF STEAM-ENGINES.

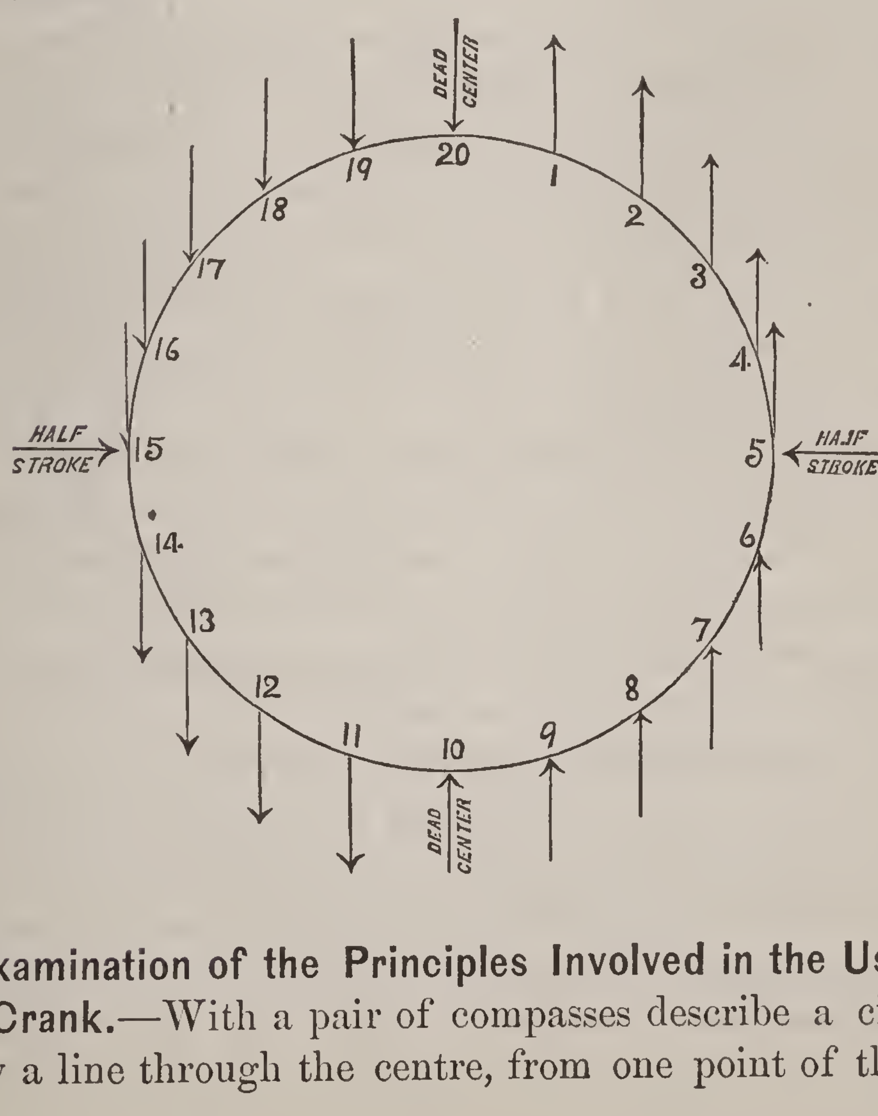
THE CRANK.

The crank being the means most generally employed for the conversion of reciprocating into rotary motion, the question has frequently arisen, whether or not there is a loss of power involved in its use; but upon examination, it will be found that the only loss of power incurred by the use of the crank is that absorbed by friction, which is the coefficient of loss in the transfer of all forces. The idea of a loss of power in the crank arose from the common error of confounding power and pressure, and forgetting that a small force exerted over a great distance in a given time may develop as much power as a large force exerted over a small distance in the same time.

An examination of the connecting-rod of an engine in motion, will show that the two ends pass over different spaces in a given time. If, for instance, in one stroke, the end of the connecting-rod that is attached to the cross-head moves through one foot, the end which is attached to the crank-pin, and makes a half revolution in the same time, passes through 1.5708 feet.

Suppose that an engine is placed with its crank on the centre, and steam is admitted; no motion will be produced,

and, consequently, there will be no power developed, and no expenditure of steam. But let the piston make a stroke; the power exerted is equal to the force or pressure acting on the piston multiplied by the space passed through, or it will be 100 foot-pounds, assuming the data of the preceding instance. During the same time, the crank-pin has passed through a space of 1.5708 feet, and the force or pressure exerted has been 63.66 pounds, so that the power exerted during this time, or the product of 1.5708 multiplied by 63.66 pounds, is 100 foot-pounds. Consequently, there is no loss of power in the use of the crank, all the power exerted on the piston being imparted to the crank.



Examination of the Principles Involved in the Use of the Crank.—With a pair of compasses describe a circle; draw a line through the centre, from one point of the in-

tersection of this line with the circle; divide the latter into 20 equal parts, 20 and 10 occurring at these points. Now suppose that the constant pressure of the steam in the cylinder be represented by 100, this pressure is communicated to the crank by means of a connecting-rod. We shall suppose that the above circle is the circle described by the crank-pin, 10 and 20 coinciding, and with the division 10 forming a right line with the centre of the crank-shaft and the centre of the cylinder; of course, the points 20 and 10 are the two points where the pressure in the cylinder has no effect in turning the crank, called the "dead-points."

The points 5 and 15 are the points at which the effect of the pressure on the piston is a maximum, decreasing each way to zero. Supposing, for simplicity, the direction of the connecting-rod to remain parallel with its first position, then the effect of any pressure communicated by it to the crank-pin is resolvable into two factors—one acting on the centre of the crank, and, of course, ineffectual in producing motion in it, and the other acting tangentially to turn the crank. The first of these is the greater at the commencement, or 20 and 10 of the circle of the crank, and the less at the points 5 and 15; while the second is the less at the first-named points and the greater at the last; and this variation is (from the well-known principles of the composition and resolution of forces) in the ratio of the sines of the angle made between the direction of the crank and that of the connecting-rod.

The subdivision of the crank-circle into 20 parts gives as the angle of each division 18°, and calling the radius of this circle 100, the sines of the respective angles formed by the crank and connecting-rods will represent the percentage of power communicated by the latter to turn the former. Thus:

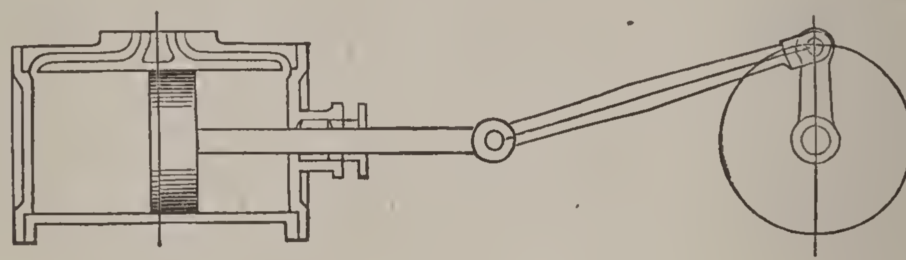
Crank-pin at	0	0°		0.0
" " "	1	18°	Sin	30.90
" " "	2	36°	"	58.78
" " "	3	54°	"	80.90
" " "	4	72°	"	95.11
" " "	5	90°	"	100.
" " "	6	108°	"	95.11
" " "	7	126°	"	80.90
" " "	8	144°	"	58.78
" " "	9	162°	"	30.90
" " "	10	180°	"	0.0
			Mean power,	63.11

The pressure of the steam on the piston forces the connecting-rod twice the length of the diameter of the circle in the same time that the crank-pin travels through a space equal to the whole circumference of this circle; and as the circumference of this circle bears to twice its diameter the ratio of 100 to 63.6, it follows that the pressures on the crank and piston are inversely as the space through which they move. The effects of moving powers may be represented, for comparison, by the product of the pressures into the spaces described in the same time.

The power of the steam in the cylinder being 100, and moving through a space represented by 2, we may represent it by 200; and the mean pressure on the crank, as shown above, being 63.11, moving through a space represented by 3.1416, we may represent its effect by their product, 198.26, differing but 1.74 from the power given out by the steam in the cylinder. This difference will appear smaller and smaller, according as we multiply the number of points in the circle, from which we calculate the mean pressure on the crank.

The two foregoing formulæ, introduced for the purpose

of showing that the crank is no consumer of power beyond the friction incidental to the motion of all machinery, but gives out all the power it receives from the steam, are somewhat different in their conclusions, being made by different calculations; but they are both approximately correct.



The annexed cut shows the position of the piston in the cylinder when the crank is at half-stroke. It will be observed that the piston is ahead of its proper position throughout the forward stroke, and that it must of necessity lag behind its position on the return-stroke; that the points of full power are not on exactly the opposite sides of the diameter of the circle described by the crank, and that a straight line passing through the centre of the crank-shaft cannot intersect both points. These irregularities, which are due to the influence of the crank and connecting-rod, entirely disappear at the end of each stroke.

The crank of a steam-engine moves six times as far while the piston is travelling the first inch of the stroke as while it is making the middle inch; a little over twice as far while the piston is moving the second inch; a trifle over $1\frac{1}{2}$ times as far while the piston moves the third inch; and less than $1\frac{1}{2}$ times as far while the piston is making the fourth inch. The crank also travels less when the piston is making the last inch of the stroke than it does while it is making the first.

TABLE

(By permission, from Auchincloss' "Link and Valve Motions.")

SHOWING THE ANGULAR POSITION OF THE CRANK-PIN CORRESPONDING WITH THE VARIOUS POINTS IN THE STROKE WHICH THE PISTON MAY OCCUPY IN THE CYLINDER.

Piston Position.	Crank Angle.	Piston Position.	Crank Angle.	Piston Position.	Crank Angle.
	Deg.		Deg.		Deg.
0.1	$36\frac{7}{8}$	$0.5625 = \frac{9}{16}$	$97\frac{1}{8}$	$0.813 = \frac{13}{16}$	$128\frac{5}{8}$
$0.125 = \frac{1}{8}$	$41\frac{3}{8}$	0.575	$98\frac{5}{8}$	0.82	$129\frac{3}{4}$
0.15	$45\frac{5}{8}$	0.6	$101\frac{1}{2}$	0.83	$131\frac{1}{4}$
0.175	$49\frac{1}{2}$	$0.625 = \frac{5}{8}$	$104\frac{1}{2}$	0.84	$132\frac{7}{8}$
0.2	$53\frac{1}{8}$	0.65	$107\frac{1}{2}$	0.85	$134\frac{3}{8}$
0.225	$56\frac{5}{8}$	$0.666 = \frac{2}{3}$	$109\frac{1}{2}$	0.86	$136\frac{1}{8}$
$0.25 = \frac{1}{4}$	60	0.68	$111\frac{1}{8}$	0.87	$137\frac{3}{4}$
0.275	$63\frac{1}{4}$	$0.687 = \frac{11}{16}$	112	$0.875 = \frac{7}{8}$	$138\frac{5}{8}$
0.3	$66\frac{3}{8}$	0.69	$112\frac{3}{8}$	0.88	$139\frac{1}{2}$
0.325	$69\frac{1}{2}$	0.7	$113\frac{5}{8}$	0.89	$141\frac{1}{4}$
$0.333 = \frac{1}{3}$	$70\frac{1}{2}$	0.71	$114\frac{7}{8}$	0.9	$143\frac{1}{8}$
0.35	$72\frac{1}{2}$	0.72	$116\frac{1}{8}$	0.91	$145\frac{1}{8}$
0.375	$75\frac{1}{2}$	0.73	$117\frac{3}{8}$	0.92	$147\frac{1}{8}$
0.4	$78\frac{1}{2}$	0.74	$118\frac{5}{8}$	0.93	$149\frac{3}{8}$
0.425	$81\frac{3}{8}$	$0.75 = \frac{3}{4}$	120	0.94	$151\frac{5}{8}$
$0.437 = \frac{7}{16}$	$82\frac{7}{8}$	0.76	$121\frac{3}{8}$	0.95	$154\frac{1}{8}$
0.45	$84\frac{1}{4}$	0.77	$122\frac{5}{8}$	0.96	$156\frac{7}{8}$
0.475	$87\frac{1}{8}$	0.78	$124\frac{1}{8}$	0.97	$160\frac{1}{8}$
$0.5 = \frac{1}{2}$	90	0.79	$125\frac{1}{2}$	0.98	$163\frac{1}{2}$
0.525	$92\frac{7}{8}$	0.8	$126\frac{7}{8}$	0.99	$168\frac{3}{4}$
0.55	$95\frac{3}{4}$	0.81	$128\frac{1}{4}$	1.00	180

TABLE

OF PISTON SPEEDS FOR ALL CLASSES OF ENGINES—STATIONARY, LOCOMOTIVE, FIRE, AND MARINE.

Small Stationary Engines	200 to 250	feet per minute.
Average	225	" "
Large Stationary Engines	275 to 350	" "
Average	312	" "
Steam Fire-Engines	200 to 300	" "
Average	250	" "
Corliss Engines	400 to 500	" "
Average	450	" "
Locomotives and Allen Engines	600 to 800	" "
Average	700	" "
Engines of River Steamers	400 to 500	" "
Average	450	" "
Engines of Ocean Steamers	400 to 600	" "
Average	500	" "

TABLE

(By permission, from Auchincloss' "Link and Valve Motions.")

SHOWING THE POSITION OF THE PISTON IN THE CYLINDER AT DIFFERENT CRANK ANGLES, ACCORDING TO THE LENGTH OF CONNECTING-ROD.

(*For Back-action Engines, the words* "Forward" *and* "Return" *must be reversed.*)

Piston Position in Cylinder.	Length of Connecting-Rod 4 to 1 of Stroke.			Length of Connecting-Rod $4\frac{1}{2}$ to 1 of Stroke.			Length of Connecting-Rod 5 to 1 of Stroke.		
	Forward Stroke.	Return Stroke.	Diff.	Forward Stroke.	Return Stroke.	Diff.	Forward Stroke.	Return Stroke.	Diff.
	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.
$0.125 = \frac{1}{8}$	$37\frac{3}{8}$	$46\frac{3}{4}$	$9\frac{3}{8}$	$37\frac{5}{8}$	$46\frac{1}{4}$	$8\frac{5}{8}$	$37\frac{7}{8}$	$45\frac{5}{8}$	$7\frac{3}{4}$
0.2	48	$59\frac{1}{2}$	$11\frac{1}{2}$	$48\frac{1}{2}$	$58\frac{3}{4}$	$10\frac{1}{4}$	$48\frac{3}{4}$	$58\frac{1}{8}$	$9\frac{3}{8}$
$0.25 = \frac{1}{4}$	$54\frac{3}{8}$	$66\frac{3}{4}$	$12\frac{3}{8}$	$54\frac{7}{8}$	66	$11\frac{1}{8}$	$55\frac{3}{8}$	$65\frac{3}{8}$	10
0.3	60	$73\frac{3}{8}$	13	61	$72\frac{5}{8}$	$11\frac{5}{8}$	$61\frac{1}{2}$	72	$10\frac{1}{2}$
$0.333 = \frac{1}{3}$	$64\frac{1}{4}$	$77\frac{5}{8}$	$13\frac{3}{8}$	$64\frac{3}{4}$	$76\frac{7}{8}$	$12\frac{1}{8}$	$65\frac{3}{8}$	$76\frac{1}{4}$	$10\frac{7}{8}$
$0.375 = \frac{3}{8}$	$68\frac{7}{8}$	$82\frac{3}{4}$	$13\frac{7}{8}$	$69\frac{1}{2}$	82	$12\frac{1}{2}$	$70\frac{1}{4}$	$81\frac{3}{8}$	$11\frac{1}{8}$
0.4	$71\frac{3}{4}$	$85\frac{5}{8}$	$13\frac{7}{8}$	$72\frac{3}{8}$	$84\frac{7}{8}$	$12\frac{1}{2}$	73	$84\frac{1}{4}$	$11\frac{1}{4}$
0.45	$77\frac{3}{8}$	$91\frac{1}{2}$	$14\frac{1}{8}$	$78\frac{1}{8}$	$90\frac{5}{8}$	$12\frac{1}{2}$	$78\frac{5}{8}$	90	$11\frac{3}{8}$
$0.5 = \frac{1}{2}$	$82\frac{7}{8}$	$97\frac{1}{8}$	$14\frac{1}{4}$	$83\frac{3}{4}$	$96\frac{1}{4}$	$12\frac{1}{2}$	$84\frac{3}{8}$	$95\frac{5}{8}$	$11\frac{3}{8}$
0.55	$88\frac{1}{2}$	$102\frac{5}{8}$	$14\frac{1}{8}$	$89\frac{3}{8}$	$101\frac{7}{8}$	$12\frac{1}{2}$	90	$101\frac{3}{8}$	$11\frac{3}{8}$
0.6	$94\frac{3}{8}$	$108\frac{1}{4}$	$13\frac{7}{8}$	$95\frac{1}{8}$	$107\frac{5}{8}$	$12\frac{1}{2}$	$95\frac{3}{4}$	107	$11\frac{1}{4}$
$0.625 = \frac{5}{8}$	$97\frac{1}{4}$	$111\frac{1}{8}$	$13\frac{7}{8}$	98	$110\frac{1}{2}$	$12\frac{1}{2}$	$98\frac{5}{8}$	$109\frac{3}{4}$	$11\frac{1}{8}$
0.65	$100\frac{1}{4}$	$113\frac{7}{8}$	$13\frac{5}{8}$	$101\frac{1}{8}$	$113\frac{1}{4}$	$12\frac{1}{8}$	$101\frac{3}{4}$	$112\frac{5}{8}$	$10\frac{7}{8}$
$0.666 = \frac{2}{3}$	$102\frac{3}{8}$	$115\frac{3}{4}$	$13\frac{3}{8}$	$103\frac{1}{8}$	$115\frac{1}{4}$	$12\frac{1}{8}$	$103\frac{3}{4}$	$114\frac{5}{8}$	$10\frac{7}{8}$
0.68	104	$117\frac{3}{8}$	$13\frac{3}{8}$	$104\frac{3}{4}$	$116\frac{3}{4}$	12	$105\frac{1}{2}$	$116\frac{1}{4}$	$10\frac{3}{4}$
0.7	$106\frac{5}{8}$	$119\frac{5}{8}$	13	$107\frac{3}{8}$	119	$11\frac{5}{8}$	108	$118\frac{1}{2}$	$10\frac{1}{2}$
0.71	$107\frac{7}{8}$	$120\frac{3}{4}$	$12\frac{7}{8}$	$108\frac{5}{8}$	$120\frac{1}{4}$	$11\frac{5}{8}$	$109\frac{3}{8}$	$119\frac{3}{4}$	$10\frac{3}{8}$
0.73	$110\frac{1}{2}$	$123\frac{1}{4}$	$12\frac{3}{4}$	$111\frac{1}{4}$	$122\frac{5}{8}$	$11\frac{3}{8}$	112	$122\frac{1}{8}$	$10\frac{1}{8}$
$0.75 = \frac{3}{4}$	$113\frac{1}{4}$	$125\frac{5}{8}$	$12\frac{3}{8}$	114	$125\frac{1}{8}$	$11\frac{1}{8}$	$114\frac{5}{8}$	$124\frac{5}{8}$	10
0.76	$114\frac{5}{8}$	$126\frac{3}{4}$	$12\frac{1}{8}$	$115\frac{3}{8}$	$126\frac{3}{8}$	11	$116\frac{1}{8}$	$125\frac{7}{8}$	$9\frac{3}{4}$
0.77	$116\frac{1}{8}$	$128\frac{1}{8}$	12	$116\frac{7}{8}$	$127\frac{5}{8}$	$10\frac{3}{4}$	$117\frac{1}{2}$	$127\frac{1}{4}$	$9\frac{3}{4}$
0.78	$117\frac{5}{8}$	$129\frac{3}{8}$	$11\frac{3}{4}$	$118\frac{3}{8}$	$128\frac{7}{8}$	$10\frac{1}{2}$	119	$128\frac{1}{2}$	$9\frac{1}{2}$
0.79	$119\frac{1}{8}$	$130\frac{3}{4}$	$11\frac{5}{8}$	$119\frac{7}{8}$	$130\frac{1}{4}$	$10\frac{3}{8}$	$120\frac{1}{2}$	$129\frac{3}{4}$	$9\frac{1}{4}$
0.8	$120\frac{1}{2}$	132	$11\frac{1}{2}$	$121\frac{1}{4}$	$131\frac{1}{2}$	$10\frac{1}{4}$	$121\frac{7}{8}$	$131\frac{1}{8}$	$9\frac{1}{4}$
0.81	$122\frac{1}{8}$	$133\frac{1}{4}$	$11\frac{1}{8}$	$122\frac{3}{4}$	$132\frac{3}{4}$	10	$123\frac{1}{2}$	$132\frac{1}{2}$	9
0.82	$123\frac{5}{8}$	$134\frac{5}{8}$	11	$124\frac{1}{2}$	$134\frac{1}{4}$	$9\frac{3}{4}$	125	$133\frac{3}{4}$	$8\frac{3}{4}$
0.83	$125\frac{3}{8}$	136	$10\frac{5}{8}$	126	$135\frac{5}{8}$	$9\frac{5}{8}$	$126\frac{5}{8}$	$135\frac{1}{8}$	$8\frac{3}{4}$
0.84	127	$137\frac{1}{2}$	$10\frac{1}{2}$	$127\frac{5}{8}$	137	$9\frac{3}{8}$	$128\frac{1}{4}$	$136\frac{3}{4}$	$8\frac{1}{2}$
0.85	$128\frac{3}{8}$	$138\frac{7}{8}$	$10\frac{1}{4}$	$129\frac{3}{8}$	$138\frac{1}{2}$	$9\frac{1}{8}$	130	$138\frac{1}{4}$	$8\frac{1}{4}$
0.86	$130\frac{1}{2}$	$140\frac{3}{8}$	$9\frac{7}{8}$	$131\frac{1}{4}$	140	$8\frac{3}{4}$	$131\frac{5}{8}$	$139\frac{3}{4}$	$8\frac{1}{8}$
0.87	$132\frac{3}{8}$	142	$9\frac{5}{8}$	133	$141\frac{3}{4}$	$8\frac{3}{4}$	$133\frac{1}{2}$	$141\frac{1}{4}$	$7\frac{3}{4}$
$0.875 = \frac{7}{8}$	$133\frac{1}{4}$	$142\frac{5}{8}$	$9\frac{3}{8}$	$133\frac{3}{4}$	$142\frac{3}{8}$	$8\frac{5}{8}$	$134\frac{3}{8}$	$142\frac{1}{8}$	$7\frac{3}{4}$

TABLE

SHOWING LENGTH OF STROKE AND NUMBER OF REVOLUTIONS FOR DIFFERENT PISTON SPEEDS IN FEET PER MINUTE.

STROKE.	Speed of Piston in Feet per Minute.														
	Ft. 200	210	220	225	230	240	250	260	270	280	290	300	320	340	350
2 in	Rev. 600	630	660	675	690.	720	750	780	810	840	870	900	960	1020	1050
3 "	400	420	440	450	460	480	500	520	540	560	580	600	640	680	700
4 "	300	315	330	337	345	360	375	390	405	420	435	450	480	510	525
5 "	240	252	264	270	276	288	300	312	324	336	348	360	384	408	420
6 "	200	210	220	225	230	240	250	260	270	280	290	300	320	340	350
7 "	170	180	188	193	197	206	214	223	231	240	248	257	274	291	300
8 "	150	157	165	169	172	180	187	195	202	210	217	225	240	255	262
9 "	133	140	147	150	153	160	166	173	180	187	193	200	213	227	233
10 "	120	126	132	135	138	144	150	156	162	168	174	180	192	204	210
11 "	109	114	120	123	125	131	136	142	147	153	158	164	174	185	191
1 ft. 0 "	100	105	110	112	115	120	125	130	135	140	145	150	160	170	175
1 " 1 "	92	97	101	104	106	111	115	120	125	129	134	138	148	157	161
1 " 2 "	86	90	94	96	98	103	107	111	116	120	124	128	137	146	150
1 " 3 "	80	84	88	90	92	96	100	104	108	112	116	120	128	136	140
1 " 4 "	75	79	82	84	87	90	94	97	101	105	109	112	120	127	131
1 " 5 "	70	74	78	79	81	85	88	92	95	99	102	106	113	120	123

TABLE

SHOWING LENGTH OF STROKE AND NUMBER OF REVOLUTIONS FOR DIFFERENT PISTON SPEEDS IN FEET PER MINUTE.

Stroke.	Speed of Piston in Feet per Minute.														
	Ft. 200	210	220	225	230	240	250	260	270	280	290	300	320	340	350
1 ft. 6 in.	67	70	73	75	76	80	83	86	90	93	97	100	106	113	116
1 " 8 "	60	63	66	68	70	72	75	78	81	84	87	90	96	100	105
1 " 10 "	55	57	60	61	63	66	68	71	74	76	79	82	88	93	96
2 " 0 "	50	52	55	56	57	60	63	65	67	70	72	75	80	85	87
2 " 3 "	44	47	49	50	51	53	55	58	60	62	64	66	72	76	78
2 " 6 "	40	42	44	45	46	48	50	52	54	56	58	60	64	68	70
2 " 9 "	36	38	40	41	42	43	45	47	49	51	53	55	58	62	64
3 " 0 "	33	35	36	37	38	40	42	43	45	47	48	50	53	56	58
3 " 3 "	31	32	33	34	35	37	38	40	41	43	44	46	50	52	54
3 " 6 "	29	30	31	32	33	34	36	37	38	40	41	43	46	48	50
3 " 9 "	27	28	29	30	31	32	33	34	36	37	39	40	43	45	47
4 " 0 "	25	26	27	28	29	30	31	32	34	35	36	38	40	42	44
4 " 3 "	23	24	25	26	27	28	29	30	32	33	34	35	38	40	41
4 " 6 "	22	23	24	25	26	27	28	29	30	31	32	33	35	38	39
4 " 9 "	21	22	23	23	24	25	26	27	28	29	30	31	33	36	37
5 " 0 "	20	21	22	22	23	24	25	26	27	28	29	30	32	34	35

THE ECCENTRIC.

The term " eccentric " is applied to all such curves as are composed of points situated at unequal distances from a central point or axis. The motion imparted to the slide-valve is generally derived from two principles of action—vibratory and rotary. When the former is the prime mover, the speed of the valve is the same throughout the stroke; or rather, if the motion is imparted by the piston, the motion of it and the valve would be equal.

Rotary motion is more often adopted than any other for the transmission of power and action; and, at present, small cranks and eccentrics are the prevailing means employed to impart the motion required for the slide-valve. The speed of the crank and the eccentric are proportionally the same in theory and practice.

Upon inspection, it will be seen that the eccentric is only a mechanical subterfuge for a small crank. This being so, a crank of the ordinary form may, and frequently is, used instead of an eccentric — the latter being a mechanical equivalent introduced, because the use of the crank is, for special reasons, inconvenient or impracticable. Since the shaft to which the eccentric is fixed makes a half revolution while the piston is making one stroke, it follows, that whatever device may be used for converting the reciprocating motion of the piston into rotary motion, the slide-valve may be actuated by an eccentric fixed on any shaft which makes a half revolution at each stroke of the piston. It will now be observed that the eccentric and valve connection is nothing more nor less than a small crank with a long connecting-rod; the valve will therefore move in precisely the same manner as the piston, and will have, in its progress from one extremity of the travel to the opposite, like irregularities. In other words, when

the eccentric arrives at the positions for cut-off and lead, the valve will be drawn beyond its true position—measured towards the eccentric—by a distance dependent on the ratio between the throw of the eccentric and the length of its rod.

When the eccentric stands at right angles to the crank, the exhaust closes, and release commences at the extremities of the stroke; consequently, if the eccentric be removed ahead 30°, not only will the cut-off take place 30° earlier, or at a crank-angle of 120° instead of 150°, but the release will take place 30° earlier, or at the 150° crank-angle.

For a cut-off, say of 140°, there would be required an angular advance of 20°, and a lap equivalent to the distance these degrees remove the eccentric centre from the line at right angles to the crank; for a cut-off at 160°, an advance of 10°, with a corresponding lap, and so on, the exhaust closure taking place respectively at the 160° and 170° crank-angles.

This closure of the exhaust confines the steam in the cylinder until the port is again opened for the return-stroke; consequently, the piston in its progress will meet with increasing resistance from the steam, which it thus compresses into a less and less volume. Such opposition, when nicely proportioned, aids in overcoming the momentum stored up in the reciprocating parts of the engine, and tends to bring them to a uniform state of rest at the end of each stroke. Since the closure of one port is simultaneous with the opening of the other, a release will take the place of the steam which was previously impelling the piston.

Within certain limits, an early release is productive of a perfect action of the parts, since an early release enables a greater portion of the steam to escape before the return-stroke commences; whereas, a release at the end of the

stroke would be attended by a resistance of the piston's progress, from the simple fact that steam cannot escape instantaneously through a small passage, but requires a certain definite portion of time, dependent on the area of the opening and the pressure of the steam.

Angular Advance. — By angular advance is meant the angle at which the eccentric stands in advance of that position which would bring the slide-valve at mid-stroke when the crank is at the dead-centres.

Throw or Stroke of the Eccentric.—The throw of the eccentric is twice the width of one steam-port, with twice the amount of lap on one side of the valve added.

How to find the Throw of any Eccentric. — Measure the eccentric from the shaft, on the heavy and light sides; the difference between the two is the throw.

Eccentrics of Marine Engines.— Eccentrics of marine engines are generally made in two pieces and bolted together, and when only a single eccentric is used, are always loose on the shaft. The eccentric is fitted on the shaft so that it can move half-way round; there are two stops on the eccentric, and one on the shaft. The shaft revolves without the eccentric until it has moved half a revolution, when the pin on the shaft comes in contact with one of the stops on the eccentric, and moves it forward in the direction of the motion.

When it becomes necessary to reverse the engine, the engineer notices whether the piston is moving up or down; if moving up, he takes the starting-bar, throws the eccentric-hook out of gear, and admits steam to the top of the piston, which immediately changes the motion of the engine; and when the shaft has moved round half a revolution, the stop on the shaft comes in contact with the second stop on the eccentric, and reverses its position on the shaft.

THE SLIDE-VALVE.

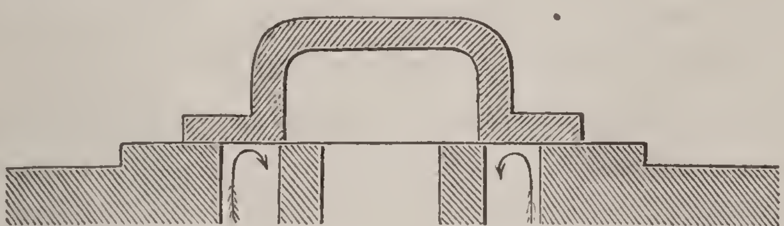
The slide-valve is that part of the steam-engine which causes the motion of the piston to be reciprocating. It is made to slide upon a smooth surface, called the valve-seat, in which there are three openings — two for the admission of steam to the cylinder alternately, while the use of the third is to convey away the waste steam. The first two are, therefore, termed the steam-ports, and the remaining one the eduction- or exhaust port.

Probably no part of the steam-engine has been the subject of more thought and discussion than the slide-valve. Its proportions have been discussed in elaborate treatises, and its movements and functions analyzed by profound mathematicians, with the aid of the most extensive formulæ and calculations; and yet, notwithstanding all these investigations, any one who undertakes to study its action, will find it difficult to discover anywhere a full or satisfactory explanation of the whole subject. If some of our learned professors would instruct engineers how to design and construct a slide-valve that would give better results, under the varying circumstances to which slide-valves are subjected, than any now in use, it would do more to make them familiar with the principles involved in the construction and working of the slide-valve than any geometrical solution of its movements, however learned, that might be given, as such theories are but very imperfectly understood by engineers in general.

In examining the special application of the slide-valve to the steam-engine, it will be necessary to consider what the requirements of the engine are; for the valves, of whatever kind, being to that machine what the lungs are to the body, must necessarily be so acted upon as to regulate the admission and escape of the steam, which is its

breath, in accordance with the conditions imposed by the motion of the piston.

The valve may be said to be the vital principle of the engine. It controls the outlet to the coal and wood pile. It is, therefore, of the highest importance that it should work practically under all circumstances — the admission of steam being one thing and its escape another, though both may be regulated by what is called one valve, because it is made in one piece, yet this is not by any means necessary. Four separate valves may be, and sometimes are, employed in stationary engines,— a steam- and an exhaust-valve at each end of the cylinder; but the functions of all these are distinctly performed by the common three-ported slide-valve.



Position of the Slide-valve when in the Centre of its Travel.

It is evident that the admission cannot continue longer, in any case, than the stroke does, so that by the time that is completed, the valve must have opened and closed the port. These conditions determine the modification of the movement which must be used, and the greatest breadth of the port for any assumed travel of valve.

When the motion of a slide-valve is produced by means of an eccentric keyed to the crank-shaft and revolving with it, the relative positions of the piston and slide-valve depend upon the relative positions of the crank and eccentric. The greatest opening of the port is half the travel of the valve; in this case the steam is admitted during the whole stroke of the piston, at the beginning of which the valve, which has no lap, is at the centre of its travel.

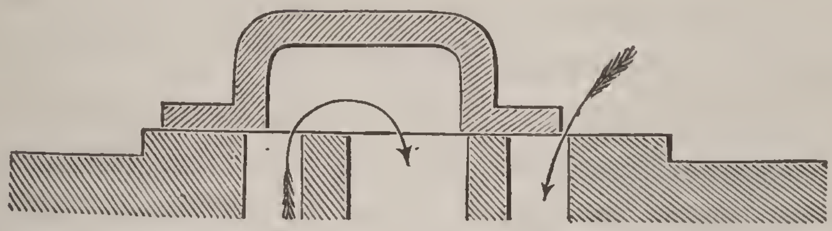
If the eccentric be so placed that at the beginning of the stroke of the piston the valve is not at the centre of its travel, the opening of the port will be reduced, and it will be closed before the piston completes its stroke. In this case, the opening of the port will be less than half the travel, by so much as the valve, at the beginning of the stroke of the piston, varies from its original central position. When the valve is at half-stroke, it will overlap the port on the opening edge to the same extent. The point in the stroke of the piston at which the port will be closed and the steam cut off, will depend upon the angular position of the eccentric at the beginning of the stroke. When the valve is so formed that, at half-stroke, the faces of the valve do not close the steam-ports internally, the amount by which each face comes short of the inner edge of the port is known as *inside clearance.*

From the nature of the valve motion, it follows that the distribution is controlled by the "outer and inner edges of the extreme-ports and of the valve." The mere width of the exhaust-port or thickness of bars is immaterial to the timing of the distribution. The extreme edges of the steam-ports and those of the valve regulate the admission and suppression; and the inner edges of the ports and the valve command the release and compression.

For every stroke of the piston, four different events occur — the admission, the suppression, the release, and the compression. The *advance* of the *valve* denotes the distance which the valve has travelled beyond its middle position when the piston is at the end of the stroke, and is known as *linear advance.*

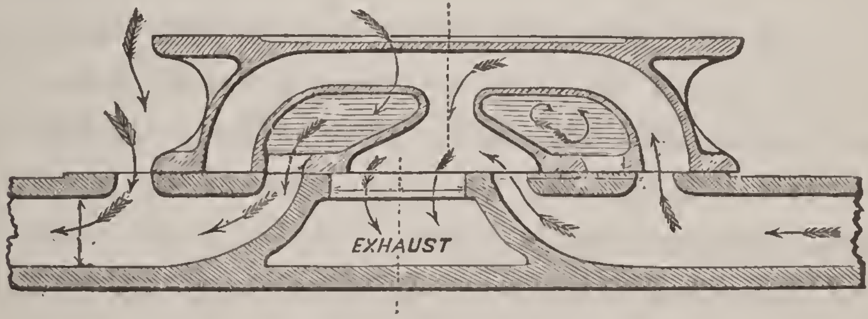
The slide-valve is more wasteful of steam than the poppet, or other forms of valve, in consequence of the long ports necessary to its use; but even with this defect, it must be conceded that nothing has as yet been introduced which

has so well answered the purpose of controlling the induction and eduction of the steam to and from the cylinder as the slide-valve.



Position of the Slide-valve when the Crank is at the "Dead-Centre."

When correctly designed and well made, the slide-valve is one of the simplest and most effective devices ever invented for its office; and, on account of its simplicity of form, durability, and positive action, it has been able to successfully compete with all other forms of valves; nor is it at all likely that it will ever be superseded by any other form for engines of moderate size, more particularly where high piston speed is an object. The friction of the slide-valve depends to a certain extent on the distance traversed by the valve. Hence it is desirable to reduce the travel as much as possible, more especially in the case of large engines. This object can be accomplished by increasing the number of ports as shown in the accompanying cut; so that one-half the travel will be sufficient to give a full port area.



Short Travel Slide-valves.

PROPORTIONS OF SLIDE-VALVES.

In order to show how to properly proportion a slide-valve, it will be necessary to give an example.

Example.—Length of valve, $8\frac{1}{2}$ inches; exhaust opening under valve, 4 inches; exhaust-port in face, $2\frac{1}{2}$ inches; inside bridge, $\frac{3}{4}$ inches thick; steam-ports, $1\frac{1}{4}$ inches wide; travel of valve, $4\frac{1}{2}$ inches; lead $\frac{1}{16}$. These proportions give a one-inch lap on each side when the valve is in the middle of its travel; the travel of this valve is 3.6 times the width of the port, which may be accepted as a good proportion for ordinary practice.

LAP ON THE SLIDE-VALVE.

The term "lap" is familiar to all steam-engineers, as denoting those portions or edges of the working-faces of the valves which extend past or beyond the ports. The object of lap is to work the steam expansively; as, when the valve has lap, it cuts off the steam supply to the piston before the latter has travelled to the end of the stroke; without lap, there would be no expansion, because admission and release would occur at the same time. Lap also induces an early and efficient release, because the lead of the exhaust, or the amount which the valve is open to the exhaust at the end of the stroke, is increased by the amount of lap on the outside. Lap on the steam side is termed the *outside lap*, while lap on the exhaust side is known as *inside lap*.

With a common slide-valve, it is not practicable to cut off the steam supply to the cylinder sufficiently early in the stroke to effect as large a degree of expansion as by some other means, because it would require the valve to have an excessive amount of outside lap, and the exhaust

would take place too early in the stroke, thus causing the piston to travel a large proportion of the latter part of the stroke without having any pressure of steam behind it.

Slide-valves work to better advantage when the lap is so proportioned as to cut off the steam at from two-thirds to three-quarters of the stroke, than at any other point, because of the comparatively long stroke of the valve when more lap is added, and the great amount of friction generated between the valve-face and its seat. The amount of inside lap is at all times to be governed by the speed at which the engine is to run, but it should never, in any case, be less than $\frac{1}{16}$ of an inch. Fast-running engines might have inside lap equal to one-half the outside lap, while engines travelling at slow speed might have a little more.

The slide-valve is sometimes so proportioned as to give it inside clearance, that is, the exhaust cavity in the face of the valve is wider than the nearest edges of the steam-ports in the seat, so that, when the valve is placed centrally over the ports, there is a clear communication, to the extent of the clearance, between each steam-port and the exhaust. The object of clearance is to give the valve a freer exhaust; but this is a grave mistake, as, in proportioning a slide-valve, the inside extreme should never exceed line and line.

Rule *for finding the Required Amount of Lap for a Slide-valve corresponding to any desired Point of Cut-off.*— From the length of stroke of piston, subtract the length of the stroke that is to be made before the steam is cut off; divide the remainder by the stroke of the piston, and extract the square root of the quotient. Multiply this root by half the throw of the valve; from the product subtract half the lead, and the remainder will give the lap required.

TABLE

SHOWING THE AMOUNT OF "LAP" REQUIRED FOR SLIDE-VALVES OF STATIONARY ENGINES WHEN THE STEAM IS TO BE WORKED EXPANSIVELY.

The travel of the valves being ascertained, and also the amount of cut-off desired, the following table shows the amount of "lap." For instance, if a valve has $\frac{7}{8}$ lap, it will overlap each steam-port $\frac{7}{8}$ of an inch when in the centre of its travel. "Lap" is not used on the valves of steam fire-engines, as none of them, that the writer is aware of, works steam expansively.

Travel of the Valve in Inches.	The Travel of the Piston where the Steam is cut off.							
	$\frac{1}{4}$	$\frac{1}{3}$	$\frac{5}{12}$	$\frac{1}{2}$	$\frac{7}{12}$	$\frac{2}{3}$	$\frac{3}{4}$	$\frac{10}{12}$
	The required "Lap."							
2	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{9}{16}$	$\frac{1}{2}$	$\frac{7}{16}$	$\frac{3}{8}$
$2\frac{1}{2}$	$1\frac{1}{16}$	1	$\frac{7}{8}$	$\frac{13}{16}$	$\frac{11}{16}$	$\frac{9}{16}$	$\frac{1}{2}$	$\frac{7}{16}$
3	$1\frac{1}{4}$	$1\frac{3}{16}$	$1\frac{1}{8}$	1	$\frac{15}{16}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{9}{16}$
$3\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{5}{16}$	$1\frac{3}{16}$	$1\frac{1}{8}$	$1\frac{1}{16}$	1	$\frac{7}{8}$	$\frac{3}{4}$
4	$1\frac{3}{4}$	$1\frac{9}{16}$	$1\frac{7}{16}$	$1\frac{5}{16}$	$1\frac{1}{4}$	$1\frac{1}{16}$	1	$\frac{13}{16}$
$4\frac{1}{2}$	2	$1\frac{13}{16}$	$1\frac{9}{16}$	$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{4}$	$1\frac{1}{8}$	$\frac{7}{8}$
5	$2\frac{1}{8}$	2	$1\frac{13}{16}$	$1\frac{9}{16}$	$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{4}$	1
$5\frac{1}{2}$	$2\frac{5}{16}$	$2\frac{3}{16}$	2	$1\frac{13}{16}$	$1\frac{5}{8}$	$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{8}$
6	$2\frac{1}{2}$	$2\frac{7}{16}$	$2\frac{3}{16}$	2	$1\frac{13}{16}$	$1\frac{5}{8}$	$1\frac{1}{2}$	$1\frac{3}{16}$
$6\frac{1}{2}$	$2\frac{3}{4}$	$2\frac{9}{16}$	$2\frac{7}{16}$	$2\frac{3}{32}$	2	$1\frac{13}{16}$	$1\frac{5}{8}$	$1\frac{1}{4}$
7	3	$2\frac{11}{16}$	$2\frac{9}{16}$	$2\frac{3}{8}$	$2\frac{3}{32}$	2	$1\frac{3}{4}$	$1\frac{7}{8}$
$7\frac{1}{2}$	$3\frac{3}{16}$	3	$2\frac{11}{16}$	$2\frac{1}{2}$	$2\frac{3}{8}$	$2\frac{3}{32}$	$1\frac{7}{8}$	$1\frac{1}{2}$
8	$3\frac{5}{16}$	$3\frac{3}{16}$	3	$2\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{3}{8}$	2	$1\frac{5}{8}$
$8\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{5}{16}$	$3\frac{3}{16}$	$2\frac{13}{16}$	$2\frac{11}{16}$	$2\frac{1}{2}$	$2\frac{1}{8}$	$1\frac{3}{4}$
9	$3\frac{13}{16}$	$3\frac{5}{8}$	$3\frac{5}{16}$	3	$2\frac{13}{16}$	$2\frac{11}{16}$	$2\frac{1}{4}$	$1\frac{7}{8}$
$9\frac{1}{2}$	4	$3\frac{13}{16}$	$3\frac{5}{8}$	$3\frac{3}{16}$	3	$2\frac{13}{16}$	$2\frac{3}{8}$	2
10	$4\frac{1}{4}$	4	$3\frac{13}{16}$	$3\frac{5}{16}$	$3\frac{3}{16}$	3	$2\frac{1}{2}$	$2\frac{1}{16}$
$10\frac{1}{2}$	$4\frac{7}{16}$	$4\frac{1}{4}$	4	$3\frac{1}{2}$	$3\frac{5}{16}$	$3\frac{1}{8}$	$2\frac{5}{8}$	$2\frac{3}{16}$
11	$4\frac{9}{16}$	$4\frac{7}{16}$	$4\frac{1}{4}$	$3\frac{5}{8}$	$3\frac{1}{2}$	$3\frac{3}{16}$	$2\frac{3}{4}$	$2\frac{1}{4}$
$11\frac{1}{2}$	$4\frac{13}{16}$	$4\frac{9}{16}$	$4\frac{7}{16}$	$3\frac{7}{8}$	$3\frac{5}{8}$	$3\frac{3}{8}$	$2\frac{7}{8}$	$2\frac{3}{8}$
12	5	$4\frac{13}{16}$	$4\frac{9}{16}$	$4\frac{1}{8}$	4	$3\frac{5}{8}$	3	$2\frac{1}{2}$

Rule *for finding the required "Lap" for Slide-valves when the Travel of the Valve is known.* — Multiply the given stroke of the valve by the decimal numbers under each point of cut-off.

Cut-off,	$\frac{1}{2}$	$\frac{7}{12}$	$\frac{2}{3}$	$\frac{3}{4}$	$\frac{5}{6}$	$\frac{7}{8}$	$\frac{11}{12}$
Multiplier,	.354	.323	.289	.250	.204	.177	.144

LEAD OF THE SLIDE-VALVE.

The object of the lead is to enable the steam to act as a cushion against the piston before it arrives at the end of the stroke, and cause it to reverse its motion easily; and also to supply the steam of full pressure to the piston from the instant it has passed its dead-centre. When the work an engine has to perform is very irregular, as is generally the case in rolling-mills, or if the different parts of the engine be badly worn or have much lost motion, considerable lead is absolutely necessary, in order that the steam admitted may offer an opposing and gradual force in a direction opposite to that in which the engine is moving, and take up the play in the different parts before the piston has reversed its motion. If the piston, after passing the centre, should meet with no opposing force, it would travel very fast during the time in which the play was being taken up, and, when the valve opened again, it would receive a check from the action of the steam which would cause it to thump or pound.

Lead, like many other details, requires the exercise of mechanical skill and judgment, as, if a valve has too much lead, not only is there a great loss of power, but the piston receives a violent shock at each end of the stroke, and it will be found almost impossible to keep the packing tight around the piston-rod in consequence of the excessive cushioning. If the amount of lead be so great as to admit steam of the full pressure to the passages and clear-

ance, the piston will have to force it back into the passages and chest, exposing the wrist- and crank-pins to a fearful shearing strain when the crank is at its weakest point — the fly-wheel travelling fast and the piston moving very slowly.

No general rule can be given for the amount of lead that would be best suited or most advantageous for all classes of engines, as that must be determined by the circumstances of construction, speed, work, etc.

In the case of vertical engines having the cylinder above and the crank below, it is customary to give less lead on the upper than on the lower port, as the wear in the valve connections has a tendency to increase the lead on the upper end. With vertical engines having the crank above and the cylinder below, these conditions are reversed. It is also customary in the case of horizontal engines to give more lead on the front than on the back end, in consequence of the reduced capacity of that end arising from the space occupied by the piston-rod.

For stationary engines, the lead varies in general practice from $\frac{1}{32}$ to $\frac{3}{16}$ of an inch; the exhaust lead being in all cases double the amount of steam lead. The average amount of lead in full gear, for freight locomotives, is $\frac{1}{12}$ of an inch; for locomotives running accommodation passenger trains, $\frac{1}{17}$ of an inch; and fast express locomotives, $\frac{1}{10}$ of an inch.

FRICTION OF SLIDE-VALVES.

All engineers agree that there is a great loss of power in working the slide-valve, but differ in the amount, from the fact that no correct data have been formed by which to make such calculations; but an idea has been very generally entertained by engineers, that the number of square

inches in a slide-valve, and the pressure of steam in pounds per square inch, represented the total pressure on its back, or that the pressure was equal to the pressure of steam per square inch on the back of a valve minus the area of the steam-ports. Such conclusions, however, are erroneous, as the number of square inches in a slide-valve, and the pounds pressure per square inch, would only represent the weight on its back, if we consider the valve as a solid block of iron with a smooth surface, resting on a smooth, solid bearing perfectly steam-tight, as then the steam would press on every square inch of surface with the same force as a dead weight laid upon it would. These conditions are never found in a slide-valve except in one position — that is, when the valve overlaps both ports, and the engine is at rest. As soon, however, as the valve is moved, the steam enters the open port, and the pressure is practically taken off that end of it.

When the valve is moved baek over the port, the steam that is shut up within the eylinder will press up against the under side of the valve-face with a force exactly equal to the pressure at that point in the stroke of the piston at whieh the valve closed. As the valve continues its stroke, the other port will be opened, and the steam that was shut up in the eylinder begins to exhaust; the pressure against the under side of the valve will be the same as that in the cylinder at the end of the stroke. This pressure is only for a brief period, sinee in engines with well-proportioned steam-ports, the time oecupied in exhausting the contents of the eylinder is very short. While the steam is entering the open port, and after the exhaust has passed through the elosed port, the pressure on the under side of the valve will be just the ordinary baek pressure. Therefore, in order to determine the pressure on a slide-valve, we must consider the pressure in the cylinder at

the time of cutting off the back pressure against the piston, the area of the ports, etc.

Rule for finding the Pressure on Slide-valves.—Multiply the unbalanced area of the valve in inches by the pressure of steam in pounds per square inch; add the weight of the valve in pounds, and multiply the sum by 0.15.

Another Rule.—Multiply the combined area of the bearing surface and ports in inches by the steam pressure in pounds per square inch on the back of the valve; multiply this product by the coefficient of friction between the two surfaces. The product will be the force required to move the valve when unbalanced.

BALANCED SLIDE-VALVES.

The removal of the weight from the back of the valve would be a step in the right direction; while all engineers agree that the use of balanced slide-valves would be a great benefit, as they would not only materially diminish the wear of valve-gear, but utilize the power wasted in overcoming the friction. There are many forms of the balance-valve that have rendered good service, but none of them have, so far, met all the requirements of a good steam-tight slide-valve. Still, as the difficulty does not seem to be insurmountable, it is more than probable that some new invention will be brought forward, or that some of the different forms of balanced-valves now in use will be so modified or improved as to accomplish the desired object.

COMPRESSION.

Compression is the term used to express the distance the piston moves in the cylinder after release or exhaust

has taken place, and the exhaust passage closed by the return-stroke of the valve, whereby the communication is cut off from the exhaust-port and that end of the cylinder. Compression takes place between the piston and cylinder-head at each end of the stroke, and the distance from the end of the cylinder at which it takes place depends on the amount of lap on the valve.

CLEARANCE.

The term clearance is used to express the extent of the space which exists between the piston, the cylinder-head, and the valve-face at each end of the stroke. For each stroke of the piston, this space must be filled with steam, which in no way improves the action of the engine, but rather increases the amount of steam to be exhausted on the return-stroke. It is, therefore, an object of great importance, in point of economy, to have the valve-face as near the bore of the cylinder as possible, in order that the cubic contents of the space in the cylinder unoccupied by the piston and the steam passages may be reduced to their smallest capacity.

AUTOMATIC CUT-OFFS.

Variable cut-off engines are engines having their steam-valves so controlled by the governor as to promptly cut off the steam at any point from zero to half-stroke; the cut-off taking place earlier or later to accommodate the varied loads on the engine and the varied pressures in the boiler, — the object being to obtain full boiler pressure at the commencement of each stroke, and maintain it to the point of cut-off, leaving the balance of the stroke to be completed by expansion, — the speed of the engine being controlled by the cut-off, and not by throttling.

Until quite recently, the common method of regulating the flow of steam from the boiler to the cylinder has been by the throttle-valve — a kind of "damper" — in the steam-pipe, which was turned as the speed of the engine increased, and choked off the supply of steam, — otherwise, the steam, in its passage from the boiler to the cylinder, had to ooze through the contracted crevices of some peculiar type of governor-valve. An engine controlled by any such device is in a condition somewhat like that of a horse restrained by a brake applied to the wheels, and compelled to exert more strength than is necessary. These relics of barbarism are fast giving place to the system referred to in the foregoing paragraph, which removes the brakes from the wheels and puts the bit in the horse's mouth instead.

Although all intelligent engineers are agreed upon the superior economy of the automatic cut-off engine, few — excepting those who have had the opportunity of making a practical comparison — are aware of the great saving in the expense of fuel, over that class of engines wherein the point of cut-off is invariably relative to stroke of piston. It is quite well understood, that the amount of work realized, as compared with the total theoretical work due the volume of steam expended, even in the most perfect engines, as shown on page 166, is a very small percentage of the whole energy; and it is, therefore, the more an object of interest to know precisely what the difference is between these two classes of engines in point of economy.

In engines with a variable expansion-gear controlled by the regulator, there is no impediment (save such as may occur at the port entrance) to the free flow of steam from the boiler to the cylinder; the regulation being effected, not by diminishing the pressure, but by cutting off in the cylinder the volume of steam necessary for each particu-

lar stroke; consequently, the only loss in pressure between the boiler and cylinder is that due to the length and number of the bends in the conducting-pipe. Whilst even in the best throttling engines, in consequence of the peculiar construction of the governor-valve and the tortuous passages through which the steam is forced to travel, the pressure in the cylinder is, in a majority of cases, reduced from three-fourths to one-half that existing in the boiler; the evil effects of which are shown on page 153.

It may seem strange that any intelligent engineer or steam-engine builder should deny the superiority of cut-off over throttling engines; and yet there are some who argue, that the economy in the use of the cut-off engine lies more in the representations than in the excellent performances, — which, of course, is an unpardonable error. In the opinion of the writer, the conditions of admission and suppression of steam to the cylinder insuring the highest grade of economy, are a full port with no intervening obstructions to impede the free flow of the steam, and a rapid movement of the cut-off or steam-valve over the port; as mere increase in the mean effective pressure, resulting from a tardy closing of the port, represents no gain during one stroke of the piston, that may be stored up and expended during the succeeding stroke; hence, any force upon the piston in excess of that required to balance the resistance, will result in a diminished economy.

The economy of a high-pressure steam-engine is exactly in proportion as its average piston pressure is higher than its pressure when it exhausts, provided the pressure does not fall below that of the atmosphere; the highest economy being attained when the stroke is commenced with full boiler pressure, and the steam quickly and completely cut off at a point in the stroke that allows the pressure to fall

to or very near that of the atmosphere; the full boiler pressure to be maintained from commencement of stroke to the point of cut-off.

SETTING VALVES.

It may seem strange that any person claiming to be an engineer should be found unable to properly set the valves of a steam-engine; and yet it is a fact, that there are thousands of persons having charge of engines, who are unfit, by want of practical knowledge, to do so correctly. This may arise from the fact that in none of the works heretofore written on the steam-engine, does there appear to be any accurate method laid down for the proper setting of valves; an omission which it is difficult to account for, as it must be admitted that the setting of the valves of steam-engines is among the most important duties which the engineer has to perform, involving, as it does, nicety of calculation and mechanical accuracy.

A slide-valve may be properly designed and constructed, and yet be unable to perform any of its proper functions, in consequence of being improperly set, as the steam may be admitted too soon or too late, and the exhaust fail to open and close at the right time, in consequence of which the useful effect of the steam is lost and the power of the engine diminished.

HOW TO SET A SLIDE-VALVE.

Place the crank at 180°, or dead-centre, and the eccentric at 90°, or at right angles with the crank; now adjust the eccentric-rod so that the rocker will stand in a perpendicular position; next place the valve centrally over the ports as shown in Fig. 1, and get it equally divided on the

rod, so that with the motion of the engine, when all is connected, the valve will travel equally to either extremes from its central position. Then turn the eccentric forward on the shaft, in the direction in which the engine is intended to run, until the valve shows the steam-port just beginning

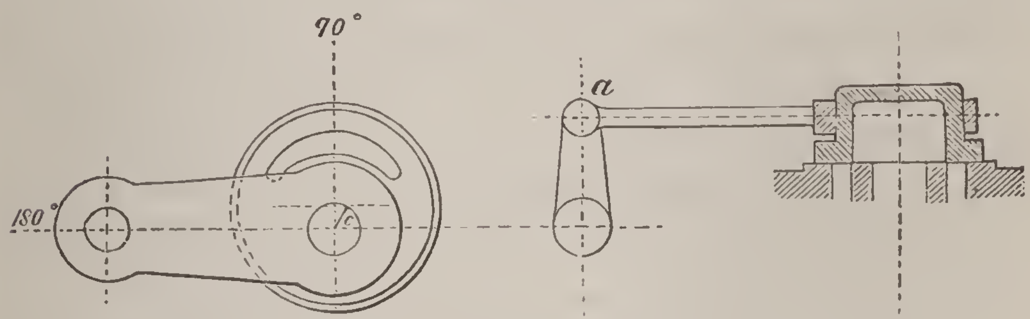


Fig. 1

to open, as in Fig. 2. If more lead be required, move the eccentric farther ahead, until the valve opens the port to the amount of lead required, when it will be found that, if the valve and ports have been laid out according to the proportions on page 155, the engine will work well.

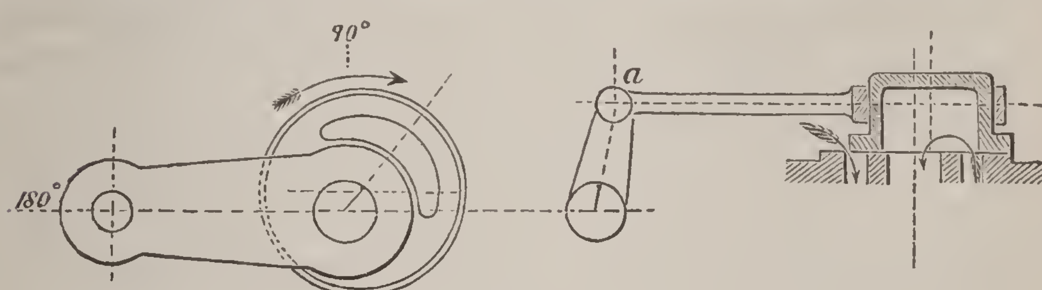


Fig. 2.

If lap be necessary, it will have to be added to the length of the valve, by either piecing the valve out at each end, or making a new one.

All valves of steam-engines, whether slide, conical, or vibratory, are set in precisely the same way, as the crank must occupy the same position when the steam- and exhaust-valves commence to open, regardless of the design or construction of the engine or valves.

To set poppet or conical valves, it is only necessary to place the crank on the dead-centre, and move the cams on the cam-bar, until the steam- and exhaust-valves have the necessary amount of lead — the throw of the cams to give the required lift of the valves being previously determined, and the movements of the cam-bar, the lifts of the valves, the speed, etc., being influenced by the action of the governor in stationary engines. But it must be understood that every different valve requires a different setting: a change of speed will necessitate a change in the position of the valve; if the throw of the valve be altered, its lead must also be altered.

One of the best helps to correct valve-setting is a good indicator, as there is nothing known which shows the action of the steam in the cylinder so correctly as this instrument. It tells exactly where the steam goes in and out of a cylinder, because it maps down the motions of the steam as determined by the motions of the valve and piston, recording faithfully the times and the pressures as they actually are, which may be very different from presumed times and pressures as shown by the mechanical movements of the valve and gear.

The valves of all engines (particularly those subjected to high temperatures, such as portable or fire engines, or, in fact, all engines attached to boilers), should be set when all the parts are warmed up to or nearly to the working temperature, as, if valves are set when all the connections are cold, in consequence of the expansion they undergo when exposed to high temperatures, they are liable to travel unequally on their seats or give unequal openings. All corrections shown by the indicator necessary to be made in the motion of valves, should be made while the parts are warm.

SETTING OUT PISTON PACKING.

One of the most important duties an engineer has to perform, is that of the setting out of piston packing; and as, like valve-setting and many other details of the steam-engine, no general instructions can be given for its adjustment, a good deal depends on the capability and intelligence of the engineer.

The first thing to be done, in order to properly adjust the packing, is to see that the piston is exactly in the centre of the cylinder. This can be ascertained by measuring, with a pair of inside calipers, from the centre of the piston to the inside of the cylinder at four different points. To insure accuracy, calipers with a long and a short leg are generally used—the short leg being inserted in the centre of the piston-head and the circle of the cylinder inscribed with the long one, which will show precisely the position of the piston in the cylinder. The rings should then be set out sufficiently tight to form a steam-tight joint with the inside of the cylinder, and no more. If the cylinder is true and in good condition, the springs of the proper tension, and the rings well proportioned and fitted, there is no reason why the piston should leak.

Whether the piston is leaky or not can be ascertained by removing the back-head of the cylinder and admitting steam to the other end. To make such a trial, the crank should be placed on the dead-centre and also at half-stroke, as many pistons perfectly steam-tight at either end would leak when at half-stroke, in consequence of the cylinder being worn larger in the middle than at the ends.

Brass or composition rings should be adjusted while the cylinder is warm, as, if set out when cold, in consequence of their great limit of expansion when heated, they become

too tight, and generate a great amount of friction. In many instances, where engines fail to develop the necessary amount of power, it is attributed to the leaky condition of the piston; and, as a remedy, the rings are set out to such an extent that, instead of the power of the engine being increased, it is materially diminished, thus aggravating the evil that was sought to be removed.

HOW TO REVERSE AN ENGINE.

Place the crank on the dead-centre, and remove the bonnet of the steam-chest; observe the amount of lead or opening that the valve has on the steam end; then loosen the eccentric, and turn it round on the shaft, in the direction in which it is intended the engine should run, until the valve has the same amount of lead on the other end. To determine whether the lead is exactly the same at both ends, a small piece of pine wood may be tapered in the shape of a wedge, and inserted in the port; the marks left on it by the edge of the port and the lip of the valve will show how far it has entered. The engine should then be turned on the other centre, for the purpose of equalizing the lead; the crank should also be placed at half-stroke, top and bottom, for the purpose of determining whether the port-opening is the same in both positions. When the crank is at half-stroke, the centre of the crank-pin is plumb with the centre of the crank-shaft.

DEAD-CENTRE.

A difficulty is often experienced in finding what is called the "dead-centre," or the position of the crank corresponding to the end of the stroke, which an experienced engineer can, in a majority of cases, tell by his eye; yet in others,

in consequence of peculiarity of design and complication of parts, he finds it very difficult. A very accurate method of finding the dead-centre in horizontal engines, is to place a spirit-level on the top or bottom of the strap of the connecting-rod, and move the crank up or down until the centre is found. Or, if this should be found inconvenient or impracticable, a circle may be described with a pair of dividers on the centre of the crank-shaft equal in diameter to the shoulder of the crank-pin; then place the spirit-level parallel with the shoulder of the crank-pin and the outer edge of the circle; then by moving the crank up or down, as the case may require, the centre can be accurately found. The centres of vertical and beam engines can be found by means of a plumb-line.

HOW TO PUT AN ENGINE IN LINE.

An engine is in line when the axis of the cylinder and the axis of the piston-rod in all positions are in one and the same straight line. This line extended should intersect the axis of the engine-shaft, and be at right angles to it. The guides should also be parallel thereto. The axis of the shaft must be level, but the centre line of the cylinder may be level, inclined, or vertical, according to the kind of engine.

Take off the cylinder-heads and remove the piston-rod, cross-head, and connecting-rod; then extend a fine line, as nearly as may be by the ordinary means of measurement, through the centre of the cylinder, and let it pass beyond the crank-pin when at outer centre; also let it extend outside the rear end of the cylinder, and firmly secure each end to some fixed object at these extreme points. Stretch this line as tightly as it will bear without breaking, and then begin to get it in exact central position by rod measurement.

Mark four points with a centre-punch at equal distances from each other around the bore of the cylinder, say, top and bottom and on each side at each end, and then, by a trial with a small pointed piece of hard wood, or wire, set the line so that, when one end of the wire rests on each of the four points successively, the other end will just feel the line; next see where this line passes the centre of the shaft. If they coincide, then the cylinder is in line with the shaft; if not, they must be put in line with each other. It is often difficult to move cylinders and shafts, and as one or the other must be removed, in some cases both, only skill and judgment can decide which to do and how to do it. No special directions can be given how to move the cylinder and shaft into line with each other, because engines are so differently constructed; but trusting to the skill of the engineer to secure these two points, the next thing to do is to set the shaft at right angles to the line, and to make it level, also. To do this, turn the shaft until the crank-pin almost touches the line; then find, by a rod or inside calipers, if the line lies evenly between the two collars of the pin; if not, note the distance from either one, then turn the shaft until the pin almost touches the line on the other side, and apply the measure to corresponding places on the collars of the pin. The difference in the measure, if any, will show which way the end of the shaft must be moved to make these measures equal.

The exchanging of the crank-pin from side to side may have to be repeated several times and remeasured, and the shaft moved, before these measures can be made equal. The shaft may require moving endwise in order to get the line to lie evenly between the two collars; but when the turning of the shaft half round brings both collars of the pin the same distance from the line, the shaft is then at right angles to the centre line of the cylinder.

In order to level the shaft by the same method, drop a plumb-line, passing by the centre of the shaft and by the centre line of the cylinder also; then by turning the pin up and down to the near touching-points of the plumb-line, and raising or lowering the outer end of the shaft until the collar on the pin is the same distance from the plumb-line in both positions, the shaft may be said to be level, or, which is the same thing, it is made at right angles to a plumb-line. It remains now to bring the guides into line with the cylinder; this may be done by direct measurement from each end of each guide (if there are two) to the line, moving them until they are parallel to the line and to one another. A spirit-level may be placed on their top faces to show how to adjust them to the horizontal; if no level is at hand, then a true square and plumb-line may be used; and if not, straight-edges placed across the guides, and measurements made down to the centre line, will determine the line of them.

PROPORTIONS OF STEAM-ENGINES ACCORDING TO THE BEST MODERN PRACTICE.

Before any correct formulæ, by which to determine the proper proportions for steam-engines, can be deduced, there are many things to be considered; permanent load, weight of moving material, nature of motion, etc.

The load on the piston-rod consists of the piston at one end and the cross-head at the other; consequently, the greater the length between these two points, the more the rod is affected. For this reason, it is obvious that, when it becomes necessary to fix the area of the piston-rod, the pressure, area of cylinder, load, and length of travel must be duly considered.

The connecting-rod being hung between a sliding and

a rotatory motion, the load is in some measure due to the length of the rod in proportion to the circle described. In the first case, the sliding point has a load on it due to the weight of the piston-rod beyond the stuffing-box, with the additional weight of the cross-head; in the second instance, the rotating surface is affected by the weight of the rod and the weight of the crank.

To determine the diameter of the crank-shaft, we must take into account the length of the crank as a lever, and the pressure of steam as the weight on the end of the same. The proportions of the crank-pin are likewise modified according to pressure, permanent load, length of stroke, shearing strain, etc.

The thickness of a steam-cylinder may be found by the following rule.—Divide the diameter of the cylinder plus 2 by 16, and deduct a $\frac{1}{100}$ part of the diameter from the quotient, the remainder will be the proper thickness.

The depth of the piston-rings should equal $\frac{1}{4}$ the diameter of the cylinder.

The thickness of the follower-plate should be the same as that of the cylinder.

The whole thickness of the piston will therefore be $\frac{1}{4}$ the diameter of the cylinder plus twice its thickness obtained by the rule above.

The diameter of the piston-rod should be from $\frac{1}{5}$ to $\frac{1}{6}$ that of the cylinder for high-pressure engines, and $\frac{1}{7}$ for condensing engines.

The diameter of the crank-shaft may be about $\frac{4}{10}$ that of the cylinder if of wrought-iron, or $\frac{5}{10}$ if of cast-iron; but it should be $\frac{5}{10}$ of wrought-iron if extra strength be required.

The length of the crank-shaft bearing should be equal to $1\frac{1}{2}$ times its diameter, and in some cases it should be twice.

The diameter of the crank-pin should be from .2 to .25 that of the cylinder. Its length should be from .275 to .35 the diameter of the cylinder.

The diameter of the wrist- or cross-head pin should be equal to that of the crank-pin, and its length the same.

The diameter of the connecting-rod, in the neck, should equal that of the piston-rod, and should increase $\frac{1}{4}$ inch in diameter, to the foot, from the neck to the middle.

The diameter of the eccentric-rod in the neck should be $1\frac{1}{4}$ times the diameter of the valve-rod, and should increase $\frac{1}{8}$ inch in diameter to the foot of the eccentric.

The diameter of the valve-rod should be from $\frac{1}{12}$ to $\frac{1}{10}$ that of the cylinder.

The diameter of the boss of the crank, if cast-iron, should equal twice that of the shaft-journal. Its depth should equal the diameter of the shaft-journal multiplied by 7.

The diameter of the crank at the pin should equal twice the diameter of the pin, and its depth at the pin should equal the diameter of the pin multiplied by 12.

The thickness of the web of the crank should equal three times the diameter of the shaft-journal.

The boss of the crank, if of wrought-iron, should equal the diameter of the shaft-journal or the pin multiplied by 4.

The thickness of the crank should equal the diameter of the shaft-journal multiplied by 6.

The area of the crank at the centre should equal that of the shaft.

The thickness of the straps should be equal to .44 of the diameter of the pins; but for engines requiring great strength, they ought to be $\frac{1}{2}$ the diameter of the pins.

The breadth of the strap should equal 1.1 times the diameter of the pin plus $\frac{1}{16}$.

The distance from the slot to the end of the strap should equal .06 of the diameter of the pin.

The breadth of the gib and key should equal 1.1 times the diameter of the pin; the thickness should equal .3 that diameter; the clearance should equal $\frac{1}{2}$ the diameter of the pin plus 2 divided by 16; the distance from the key-slot to the end of the block should equal .44, the diameter of the pin.

The diameter of the steam-pipe should be the same as that of the crank-pin, or from .2 to .25, the diameter of the cylinder.

The diameter of the exhaust-pipe should be from .25 to .3, the diameter of the cylinder.

The length of the cross-head bearings should be equal to $\frac{2}{3}$ the diameter of the cylinder, and their breadth to $\frac{5}{24}$ of the same.

The diameter and length of the rock-shaft bearing, if subjected to torsion strain, should be from $\frac{1}{3}$ to $\frac{1}{2}$ the diameter of the engine-shaft; if not subjected to torsion, $\frac{1}{4}$ the diameter of the engine-shaft will be sufficient.

The diameter of the rock-shaft pin should not be less than that of the valve-stem; and if an overhanging pin, it should be from $1\frac{1}{4}$ to $1\frac{1}{2}$ times the diameter of the valve-stem.

In order to make the proportions more plain, it may be advisable to introduce an example; say, for instance, an engine with a cylinder 12 inches in diameter and 30 inches stroke. Thickness of cylinder, $\frac{3}{4}$ inch; depth of piston-ring, 3 inches; diameter of piston-rod, $1\frac{1}{16}$ inches; diameter of crank-shaft, if of wrought-iron, 4.8 to 5 inches, if of cast-iron, 8 to $8\frac{1}{2}$ inches; length of bearing, $7\frac{1}{2}$ inches; diameter of crank-pin, 2.4 to 3 inches; length of crank-pin, 3.3 to 4 inches; diameter of connecting-rod in the neck, $1\frac{1}{16}$ inches; diameter of eccentric-rod, $1\frac{1}{4}$ inches;

diameter of valve-rod, 1 inch; diameter of wrist-pin, 2.4 to 3 inches; length of wrist-pin from 3.3 to 4 inches; thickness of sub-straps, $1\frac{3}{8}$ inches; breadth of straps, $3\frac{3}{8}$ inches; distance from slot to end, 1.8; breadth of gib and key, $3\frac{7}{8}$ inches; thickness of gib and key, $\frac{3}{4}$ inch; clearance, 2 inches to .218 inch; from key-slot to end of block, $1\frac{3}{8}$ inches; area of steam-port, $7\frac{1}{2}$ inches; length of port, 7.2 inches; width, 1 inch; width of exhaust-port, $1\frac{1}{2}$ inches; diameter of steam-pipe, 3 inches; diameter of exhaust-pipe, $3\frac{1}{2}$ inches.

TABLE

SHOWING THE PROPER THICKNESS FOR STEAM-CYLINDERS OF DIFFERENT DIAMETERS.

Diam. of Cylinder.	Thickness.	Diam. of Cylinder.	Thickness.
6 inch.	$\frac{5}{8}$ inch.	14 inch.	1 inch.
8 "	$\frac{11}{16}$ "	15 "	$1\frac{1}{16}$ "
9 "	$\frac{3}{4}$ "	17 "	$1\frac{1}{8}$ "
10 "	$\frac{13}{16}$ "	18 "	$1\frac{3}{16}$ "
11 "	$\frac{7}{8}$ "	19 "	$1\frac{1}{4}$ "
12 "	$\frac{15}{16}$ "	21 "	$1\frac{3}{8}$ "

The foregoing thicknesses include the proper allowance for reboring. But when the speed of the piston is intended to exceed 300 feet per minute, $\frac{1}{16}$ of an inch should be added per 100 feet to the thickness given.

The following table, however, is more in accordance with modern practice.

Diam. of Cylinder.	Thickness.	Diam. of Cylinder.	Thickness.
6 in.	.440	20 in.	1.175
8 "	.545	22 "	1.280
10 "	.650	24 "	1.385
12 "	.755	26 "	1.490
14 "	.860	28 "	1.595
16 "	.965	30 "	1.700
18 "	1.070		

Rule *for finding the required Diameter of Cylinder for an Engine of any given Horse-power, the Travel of Piston and available Pressure being decided upon.*— Multiply 33,000 by the number of horse-power; multiply the travel of piston in feet per minute by the available pressure in the cylinder. Divide the first product by the second; divide the quotient by the decimal .7854. The square root of the last quotient will be the required diameter of cylinder.

THE INVENTION AND IMPROVEMENT OF THE STEAM-ENGINE.

A Machine receiving at distant times and from many hands new combinations and improvements, and becoming at last of signal benefit to mankind, may be compared to a rivulet, swelled in its course by tributary streams, until it rolls along, a majestic river, enriching in its progress states and provinces. In retracing the current from where it mingles with the ocean, the pretensions of even ample subsidiary streams are merged in our admiration of the master flood, glorying, as it were, in its expansion. But as we continue to ascend, those waters, which nearer the sea would have been disregarded as unimportant, begin to rival in magnitude, and divide attention with the parent stream, until at length, on approaching the fountains of the river, it appears trickling from the rock, or oozing from among the flowers of the valley.

So also in developing the rise of a machine, a coarse instrument or a toy may be recognized as the germ of that production of mechanical genius whose power and usefulness have stimulated our curiosity to mark its changes and to trace its origin. The same feeling of gratitude which attached reverence to the place from whence mighty rivers have sprung, also clothed it, as it were, with

divinity, and raised altars in honor of the inventors of the saw, the plough, and the loom. To those who are familiar with modern machinery, the construction of these implements may appear to have conferred but slight claim to the respect in which their authors were held in ancient times. Yet, artless as they seem, their use first raised man above the beasts of the field, by incalculably diminishing the sum of human labor.

From the important and increasing influence of the steam-engine on human affairs, controversies have frequently arisen between writers of different nations respecting the claims of their countrymen to its invention. But the steam-engine cannot be said to be the invention of any one man or belong to any nationality, but to be a combination of the scattered devices of a number of ingenious men, whose fortune it was more frequently to fail than to succeed, but who did not consider such failures a good reason for abandoning their cherished objects, or allowing them to fall into oblivion, being aware that practice is progressive, and that the mechanical difficulties which so much embarrassed them would be removed as they advanced towards greater perfection, and that the schemes that had failed, as well as those that were doubtful, should be considered as seeds drifting on a common field which some random step would fix in the soil and quicken into life.

It also not unfrequently happened that some of those discoveries that conferred such benefits on mankind were the result of mere accident, and that, while in the pursuit of some peculiar objects, others of greater importance were often unfolded. Such was the case of the steam-engine, as it was only the raising of water directly by fire that exercised the ingenuity of Worcester, Moreland, Papin, Savery, and Newcomen. But their labors resulted in the

production of the most important and valuable machine that the arts have ever presented to man — the steam-engine.

The earliest records extant of a machine producing useful effect by the vapor of boiling water, is the Eolipile of Heron, of Alexandria, who lived about 280 years B. C., and which may be said to be the "germ" of the modern steam-engine. The Eolipile was a hollow globe resting on legs, which, being filled with water and placed over a fire, allowed the increasing steam to escape through a small orifice at the top, which had the effect of producing a draught similar to that of the blower-pipe in the chimney of a locomotive. The Eolipile was very extensively used in Egypt for blowing fires, increasing draught in chimneys, diffusing perfumes, for idol worship, etc.

In 1543, Blasco de Garay, a Spaniard, is said to have constructed a steamboat of 200 tons, in the harbor of Barcelona, Spain, and used steam as a motive power for its propulsion. From this it was claimed that the steam-engine was invented in Spain, and that Blasco de Garay should be regarded as the inventor. But as the nature and construction of his engine are not mentioned in the claim, we are left to form our own opinion. The probabilities are that De Garay used a machine constructed on the same principle as Savery's, Papin's, or Leopold's, to raise water upon an overshot-wheel fixed on the same axle as the paddles. De Garay is also claimed to be the inventor of the paddle-wheel, which is evidently a mistake, as the same honor was claimed by Papin, Savery, Jouffroy, Symington, and a host of others. In fact, the principle of the paddle-wheel is equally as old as the wind-mill.

In 1630, Branca, an Italian, is claimed to have invented a machine which produced useful effect by the elastic force of steam. But from the most reliable accounts, Branca's

machine was constructed on the same principle as the "breast" water-wheel, and received its motion from steam issuing from an orifice in a vessel similar to the Eolipile.

In 1663, the Marquis of Worcester is said to have constructed an engine by which motion was given to a piston by means of steam. But the account of his invention is so ambiguous, as to lead to the belief that his machine was similar to those of Papin and Savery, which could not be said to belong to the same class as the modern steam-engine, nor could their inventors claim to have contributed anything to the invention of the latter, except to make their contemporaries more familiar with the mechanical properties of steam, as their ideas seem to have been wholly confined to the raising of water in the most direct manner. There is no evidence to show that either Papin or Savery ever thought of a piston.

In 1710, Newcomen made the first steam-engine in England that could be said to be worthy of the name. To Newcomen belongs the honor of not only laying the foundation of the modern steam-engine, but also of attracting the attention of ingenious men to its improvement. Newcomen was also claimed to be the discoverer of the principle of condensation; but this is evidently a mistake, as the alchemists were familiar with the formation of a vacuum by the condensation of steam, and with raising water into it by atmospheric pressure, long before Newcomen's time.

In 1720, Leopold and Trevithick invented their high-pressure engine, which was greatly admired, though useless and impracticable, since, when the steam raised the piston to the upper end of the cylinder, it would remain there, as there was no counter-pressure to cause it to descend. But the engines of Newcomen and Leopold, with all their imperfections, were the connecting links between the

machines of Heron, De Garay, Papin, and Savery and the engines of Watt, Fitch, and Oliver Evans, as they opened the way for the introduction of the crank- and the fly-wheel, which changed completely the character of the old engines.

In 1764, James Watt made the first engine in England that bore any resemblance to steam-engines of the modern type; and in 1786, he patented and made public his great improvements, among which was separate condensation — to realize the importance of which requires careful study and thorough mechanical knowledge even at this late day. When we consider that to him all was comparatively novel, we pause in astonishment at the stupendous results of his invention; and yet it was eight years before he succeeded in getting any one to try it, and had not a fortunate chance at that period introduced him to a liberal, enlightened, and enterprising man in Boulton, another eight years of fruitless efforts might probably have been undergone, or even the full appreciation of the invention indefinitely delayed, in which case the whole of that vast career of progress on which the human race entered as a consequence of the discovery of the steam-engine would have been postponed.

In 1787, John Fitch, of Connecticut, with the aid of a common blacksmith, built in Philadelphia the first condensing-engine ever heard of on this continent, and this without any knowledge of Watt's improvements in condensing-engines, as it was in the previous year that the latter patented and made them public — consequently, there is every reason to believe that John Fitch was entirely ignorant of them.

In 1793, Oliver Evans, a native of Philadelphia, invented the high-pressure engine; and to him must be awarded the credit of having built, and put in operation, the first

practically useful high-pressure steam-engine. The high-pressure engine of Oliver Evans had immense advantages, in cheapness and simplicity, over the more expensive and complicated condensing-engine of Watt; and ever since the days of Oliver Evans, the high-pressure engine has continued to be the standard steam-engine for land purposes wherever steam has been introduced as a motive-power. England, ever true and grateful to her own genius, has fitly honored her greatest inventor, Watt; while America has suffered the genius of Oliver Evans, John Fitch, and Robert Fulton to die unrewarded in life, and forgotten in the grave, though she has not forgotten to profit by their inventions.

In 1807, Robert Fulton, a man whom we should never forget to honor, established the success of steam navigation. He was also the first to apply the paddle-wheel, in its present form, to the propulsion of vessels, and to introduce steam ferry-boats in this country.

It is quite interesting to follow the various improvements that have been made upon the steam-engine at different times, and to see how it has been brought to its present form. The cylinder and piston were used for raising water long before the advent of the steam-engine; and in the early forms of the latter, one end of the cylinder was open to the atmosphere, while the piston was nothing more than a flat wooden float, connected with a beam and sector by means of a rod and chain. But in 1776, Blakey made the piston steam-tight by means of a stratum of hemp saturated with grease, for which he obtained a patent.

In 1804, Oliver Evans made the cylinder a steam-tight vessel, and introduced steam alternately above and below the piston. In this arrangement lay the vital energy of the steam-engine, as all the other parts are but appendages

to the cylinder and piston. They may be removed, and the energy of the machine still remains; but take away either cylinder or piston, and the whole becomes as inert as the limbs of an animal whose heart has ceased to beat. The metallic piston-packing, now so universally used, was invented by Aiken in 1836, and the stuffing-box, by La Hire, in 1716.

Murdock was claimed to be the inventor of the crank, but the same device had been used in the common foot-lathe centuries before. After many years of experiment, it was finally adopted by Pickard; after which Watt patented a much more complicated method of converting reciprocating into rotary motion, which was called the sun and planet motion, but it went out of use after repeated trials with the crank.

In the first steam-engines, the admission of the steam to the cylinder was regulated by means of a stop-cock, which required constant attention, as it had to be opened and closed at each stroke of the piston; but a boy, named Potter, employed in this service, stimulated by the love of play, ingeniously added cords to the levers by which the cocks were turned, and, connecting the other ends of the cords to the working-beam, rendered the machine self-acting. Beighton afterwards substituted iron rods.

The parallel rods, now so universally superseded by the guides, were invented by Watt in 1790. He was also the inventor of the condenser, and the first to attach an air-pump to the steam-engine, though the latter device was used for other purposes previous to Watt's time. Watt was also the inventor of the governor; but that indispensable adjunct of the steam-engine remained very imperfect down to 1848, when George Corliss invented and constructed the first steam-engine governor that could be said to be worthy of the name.

The slide-valve was invented by Murray, in 1810. In 1832, R. L. Stevens invented the poppet-valve. In 1841, he invented the Stevens' cut-off valve-gear, which is still used on a large number of marine engines. He was also the inventor of the now universally known American skeleton walking-beam, with cast-iron centre and forged straps.

In 1848, the automatic cut-off, which has almost universally superseded that relic of barbarism, the throttle-valve, was invented by George Corliss. The combination of the foregoing devices has made up the modern steam-engine — the great prime mover of man. And, strange as it may seem, nearly all the important improvements in the steam-engine have been achieved by men of other callings than that of engineers, which goes to strengthen the often repeated assertion, that where it is possible to make any improvement in a machine, it would be more likely to be discovered by men of natural genius, untrammelled by the routine of any special trade, than by men who, from force of habit, become unreasoning creatures.

While the merit of the discovery of the expansive properties of steam is due to Hornblower, who obtained a patent for his invention in 1781, the honor of first working it expansively belongs to Robert L. Stevens, as he invented the cut-off valve in 1813; and there does not appear to be any evidence that steam was worked expansively in England previous to that time. Thus it will be seen that most of the great improvements made in the steam-engine, more particularly the high-pressure engine, were the results of American genius; and that America has produced a class of engineers who, in spite of many difficulties, have produced effects wonderful even to themselves.

Although Archimedes was the inventor, or at least the

alleged inventor, of the screw, Col. John Stevens, an American, was the first to adapt it to the purposes of the propulsion of vessels, in 1804. He was also the inventor of the tubular boiler.

The spring-gauge, that invaluable attachment of the steam-boiler, is also an American invention, and with the exception of the Bourdon (French) and Schæffer (Prussian), all the spring-gauges in use in the United States, some thirty in number, are American inventions.

SIGNIFICATION OF SIGNS USED IN CALCULATIONS.

$=$	signifies	Equality,	as 3 added to 2 $= 5$.
$+$	"	Addition,	" $4 + 2 = 6$.
$-$	"	Subtraction,	" $7 - 4 = 3$.
$\times$	"	Multiplication,	" $6 \times 2 = 12$.
$\div$	"	Division,	" $16 \div 4 = 4$.
$: :: :$	"	Proportion,	" 2 is to 3, so is 4 to 6.
$\sqrt{}$	"	Square Root,	" $\sqrt{16} = 4$.
$\sqrt[3]{}$	"	Cube Root,	" $\sqrt[3]{64} = 4$.
3^2	"	3 is to be squared,	" $3^2 = 9$.
3^3	"	3 is to be cubed,	" $3^3 = 27$.

$\overline{2 + 5} \times 4 = 28$ signifies that two, three, or more numbers are to be taken together, as $2 + 5 = 7$, and 4 times $7 = 28$.

$\sqrt{5^2 - 3^2} = 4$ signifies that 3 squared is taken from 5 squared, and the square root of the difference $= 4$.

$\sqrt[3]{\dfrac{10 \times 6}{15}} = 1.587$ signifies that where 10 is multiplied by 6 and divided by 15, the cube root of the quotient $= 1.587$.

DECIMALS.

Decimal Arithmetic is of Hindoo origin, and was introduced into Arabia about one thousand years ago, from whence it was diffused throughout Europe and the entire civilized world. The base, 10, originated from the ten fingers, which were used for counting before characters were formed to denote numbers. The base, 10, admits of only one binary division, which gives the prime number 5 without fraction. The trinary divisions give an endless number of decimals.

Decimal Fractions are fractions in which the denominator is a unit, or 1 with ciphers annexed, in which case they are commonly expressed by writing the numerator only with a point before it, by which it is separated from whole numbers; thus, .5, which denotes five-tenths, $\frac{5}{10}$; .25, that is, $\frac{25}{100}$.

DECIMAL EQUIVALENTS OF INCHES, FEET, AND YARDS.

Fractions of an Inch.		Decimals of an Inch.		Decimals of a Foot.
	—	.0625	=	.00521
$\frac{1}{8}$	—	.125	=	.01041
	—	.1875	=	.01562
$\frac{1}{4}$	—	.25	=	.02083
	—	.3125	=	.02604
$\frac{3}{8}$	—	.375	=	.03125
	—	.4375	=	.03645
$\frac{1}{2}$	—	.5	=	.04166
	—	.5625	=	.04688
$\frac{5}{8}$	—	.625	=	.05208
	—	.6875	=	.05729
$\frac{3}{4}$	—	.75	=	.06250
	—	.8125	=	.06771
$\frac{7}{8}$	—	.875	=	.07291
	—	.9375	=	.07812
1 inch	—	1.00	=	.08333

Inch.		Feet.		Yards.
1	=	.0833	=	.0277
2	=	.1666	=	.0555
3	=	.25	=	.0833
4	=	.3333	=	.1111
5	=	.4166	=	.1389
6	=	.5	=	.1666
7	=	.5833	=	.1944
8	=	.6666	=	.2222
9	=	.75	=	.25
10	=	.8333	=	.2778
11	=	.9166	=	.3055
12	=	1.000	=	.3333

DECIMAL EQUIVALENTS OF POUNDS AND OUNCES.

Oz.	Lbs.	Oz.	Lbs.	Oz.	Lbs.	Oz.	Lbs.	Oz.	Lbs.
¼	.015625	3	.1875	6½	.40625	10	.625	13½	.84375
½	.03125	3½	.21875	7	.4375	10½	.65625	14	.875
¾	.046875	4	.25	7½	.46875	11	.6875	14½	.90625
1	.0625	4½	.28125	8	.5	11½	.71875	15	.9375
1½	.09375	5	.3125	8½	.53125	12	.75	15½	.96875
2	.0125	5½	.34375	9	.5625	12½	.78125	16	1.
2½	.15625	6	.373	9½	.59375	13	.8125		

USEFUL NUMBERS IN CALCULATING WEIGHTS AND MEASURES, ETC.

Feet	multiplied by	.00019	equals	miles.
Yards	"	.0006	"	miles.
Links	"	.22	"	yards.
Links	"	.66	"	feet.
Feet	"	1.5	"	links.
Square inches	"	.007	"	square feet.
Circular inches	"	.00546	"	square feet.
Square feet	"	.111	"	square yards.
Acres	"	.4840	"	square yards.
Square yards	"	.0002066	"	acres.
Width in chains	"	.8	"	acres per m.
Cube feet	"	.04	"	cube yards.
Cube inches	"	.00058	"	cube feet.
U. S. bushels	"	.0495	"	cube yards.
U. S. bushels	"	1.2446	"	cube feet.
U. S. bushels	"	2150.42	"	cube inches.
Cube feet	"	.8036	"	U. S. bushels.
Cube inches	"	.000466	"	U. S. bushels.
U. S. gallons	"	.13367	"	cube feet.
U. S. gallons	"	.231	"	cube inches.
Cube feet	"	7.48	"	U. S. gallons.
Cylindrical feet	"	5.874	"	U. S. gallons.
Cube inches	"	.004329	"	U. S. gallons.
Cylindrical inches	"	.0034	"	U. S. gallons.
Pounds	"	.009	"	cwt.
Pounds	"	.00045	"	tons.
Cubic foot of water	"	62.5	"	lbs. avoird.
Cubic inch of water	"	.03617	"	lbs. avoird.
Cylindrical foot of water	"	49.1	"	lbs. avoird.

Cylindrical inch of water	mult. by	.02842	equals	lbs. avoird.
U. S. gallons of water	"	13.44	"	1 cwt.
U. S. gallons of water	"	268.8	"	1 ton.
Cubic feet of water	"	1.8	"	1 cwt.
Cubic feet of water	"	35.88	"	1 ton.
Cylindrical foot of water	"	6.	"	U. S. gallons.
Column of water, 12 in. high, 1 in. diameter			"	341 lbs.
183.346 circular inches			"	1 square foot.
2200 cylindrical inches			"	1 cubic foot.
French mètres	multiplied by	3.291	"	feet.
Kilogrammes	"	2.205	"	avoird. lbs.
Grammes	"	.002205	"	avoird. lbs.

DECIMAL EQUIVALENTS TO THE FRACTIONAL PARTS OF A GALLON OR AN INCH.

(The Inch or Gallon being divided into 32 parts.)

In multiplying decimals, it is usual to drop all but the first two or three figures.

Decimals.	Gallon or Inch.	Gills.	Pints.	Quarts.	Decimals.	Gallon or Inch.	Gills.	Pints.	Quarts.	Decimals.	Gallon or Inch.	Gills.	Pints.	Quarts.
.03125	1–32	1	$\frac{1}{4}$	$\frac{1}{8}$	.375	3–8	12	3	$1\frac{1}{2}$	.71875	23–32	23	$5\frac{3}{4}$	$2\frac{7}{8}$
.0625	1–16	2	$\frac{1}{2}$	$\frac{1}{4}$	.40625	13–32	13	$3\frac{1}{4}$	$1\frac{5}{8}$	.75	3–4	24	6	3
.09375	3–32	3	$\frac{3}{4}$	$\frac{3}{8}$	.4375	7–16	14	$3\frac{1}{2}$	$1\frac{3}{4}$	.78125	25–32	25	$6\frac{1}{4}$	$3\frac{1}{8}$
.125	1–8	4	1	$\frac{1}{2}$	.46875	15–32	15	$3\frac{3}{4}$	$1\frac{7}{8}$	.8125	13–16	26	$6\frac{1}{2}$	$3\frac{1}{4}$
.15625	5–32	5	$1\frac{1}{4}$	$\frac{5}{8}$	.5	$\frac{1}{2}$	16	4	2	.84375	27–32	27	$6\frac{3}{4}$	$3\frac{3}{8}$
.1875	3–16	6	$1\frac{1}{2}$	$\frac{3}{4}$	.53125	17–32	17	$4\frac{1}{4}$	$2\frac{1}{8}$	.875	7–8	28	7	$3\frac{1}{2}$
.21875	7–32	7	$1\frac{3}{4}$	$\frac{7}{8}$	.5625	9–16	18	$4\frac{1}{2}$	$2\frac{1}{4}$	.90625	29–32	29	$7\frac{1}{4}$	$3\frac{5}{8}$
.25	1–4	8	2	1	.59375	19–32	19	$4\frac{3}{4}$	$2\frac{3}{8}$	.9375	15–16	30	$7\frac{1}{2}$	$3\frac{3}{4}$
.28125	9–32	9	$2\frac{1}{4}$	$1\frac{1}{8}$	.625	5–8	20	5	$2\frac{1}{2}$	.96875	31–32	31	$7\frac{3}{4}$	$3\frac{7}{8}$
.3125	5–16	10	$2\frac{1}{2}$	$1\frac{1}{4}$	.65625	21–32	21	$5\frac{1}{4}$	$2\frac{5}{8}$	1.000	1	32	8	4
.34375	11–32	11	$2\frac{3}{4}$	$1\frac{3}{8}$	.6875	11–16	22	$5\frac{1}{2}$	$2\frac{3}{4}$					

UNITS.

Unit of Heat. — The unit of heat varies: the French unit of heat, called a "*caloric*," is the amount of heat necessary to raise one kilogramme (2.2046215 pounds) of water one degree Centigrade, or from 0° C. to 1° C. In this country and in England the amount of heat necessary to raise one pound of water one degree Fahrenheit, or from 32° Fah. to 33° Fah., is taken as the unit of heat.

Unit of Length.—The unit of length used in this country and in England is the yard, the length of which has been determined by means of a pendulum, vibrating seconds in the latitude of London, in a vacuum and at the level of the sea. The length of such a pendulum is to be divided into 3,913,929 parts, and 3,600,000 of these parts are to constitute a yard. The yard is divided into 36 inches, so that the length of the seconds pendulum in London is 39.13929 inches.

The French unit of length, called the mètre, has been taken as being the ten-millionth part of the quadrant of a meridian passing through Paris; that is to say, the ten-millionth part of the distance between the equator and the pole, measured through Paris. It is equal to 39.3707898 inches. The mètre is divided into one thousand millimètres, one hundred centimètres, and ten decimètres; while a decamètre is ten mètres, a hectomètre one hundred mètres, a kilomètre one thousand mètres, and a myriamètre ten thousand mètres. The following table gives the value of these measurements in English inches and yards:

	In English Inches.	In English Yards.
Millimètre	0.03937	0.0010936
Centimètre	0.39371	0.0109363
Decimètre	3.93708	0.1093633
Mètre	39.37079	1.0936331
Decamètre	393.70790	10.9363310
Hectomètre	3937.07900	109.3633100
Kilomètre	39370.79000	1093.6331000
Myriamètre	393707.90000	10936.3310000

One English yard is equal to 0.91438 mètre; while one mile is equal to 1.60931 kilomètres.

Unit of Surface.—For the unit of surface, the square inch, foot, and yard adopted in this country and in Eng-

land are replaced in the metric system by the square millimètre, centimètre, decimètre, and mètre.

1 square mètre	=	1.1960333 square yards.
1 square inch	=	6.4513669 square centimètres.
1 square foot	=	9.2899683 square decimètres.
1 square yard	=	0.83609715 square mètre.

Unit of Capacity. — The cubic inch, foot, and yard furnish measures of capacity; but irregular measures, such as the pint and gallon, are also used in this country and in England. The gallon contains ten pounds avoirdupois weight of distilled water at 62 Fah.; the pint is one-eighth part of a gallon.

The French unit of capacity is the cubic decimètre or litre, equal to 1.7607 English pints, or 0.2200 English gallon; and we have cubic inches, decimètres, centimètres, and millimètres.

1 litre	=	61.027052 cubic inches.
1 cubic foot	=	28.315311 litres.
1 cubic inch	=	16.386175 cubic centimètres.
1 gallon	=	4.543457 litres.

Unit of Weight.—The unit of weight used in this country and in England, viz., the pound, is derived from the standard gallon, which contains 277.274 cubic inches; the weight of one-tenth of this is the pound avoirdupois, which is divided into 7000 grains.

The French measures of weight are derived at once from the measures of capacity, by taking the weight of cubic millimètres, centimètres, decimètres, or mètres of water at its maximum density, that is at 4° C. or 39° Fah. A cubic mètre of water is a tonne, a cubic decimètre a kilogramme, a cubic centimètre a gramme, and a cubic millimètre a milligramme.

	In English Grains.	In Pounds Avoirdupois 1 pound = 700 grammes.
Milligramme ($\frac{1}{1000}$ part of a gramme)	0.015432	0.0000022
Centigramme ($\frac{1}{100}$ part of a gramme).	0.154323	0.0000220
Decigramme ($\frac{1}{10}$ part of a gramme)...	1.543235	0.0002205
Gramme..................................	15.432349	0.0022046
Decagramme (10 grammes)............	154.323488	0.0220462
Hectogramme (100 grammes)..........	1543.324880	0.2204621
Kilogramme (1000 grammes)	15432.348800	2.2046213
Myriagramme (10000 grammes).......	154323.488000	22.0462126

Unit of Time or Duration. — The unit of time or duration is the same for all civilized countries. The twenty-fourth part of a mean solar day is called an hour, which contains sixty minutes, which again is divided into sixty seconds. The second is universally used as the unit of duration.

Another unit of time is the period occupied by the earth in making one revolution around the sun, in reference to an assumed fixed star, which unit is called a sidereal year, and contains 365 days, 6 hours, 9 minutes, 9.6 seconds mean solar time.

Unit of Velocity. — The units of velocity adopted by different scientific writers vary somewhat; the most usual, perhaps, in regard to sound, falling bodies, projectiles, etc., is the velocity of feet or mètres per second. In the case of light and electricity, miles and kilomètres per second are employed.

Unit of Work. — In this country and in England the unit of work is usually the foot-pound, viz., the force necessary to raise one pound weight one foot above the earth in opposition to the force of gravity. A horse-power is equal to 33,000 pounds raised to a height of one foot in one minute of time.

In France the kilogrammètre is the unit of work, and

is the force necessary to raise one kilogramme to a height of one mètre against the force of gravity. One kilogram-mètre = 7.233 foot-pounds. The cheval-vapeur is nearly equal to the English horse-power, and is equivalent to 32,500 pounds raised to a height of one foot in one minute of time. The force competent to produce a velocity of one mètre in one second, in a mass of one gramme, is sometimes adopted as a unit of force.

Unit of Pressure. — The pressure of the atmosphere at the level of the ocean, with the barometer at 30 inches, is taken as the unit in estimating and comparing pressures and elastic forces.

THE METRIC SYSTEM OF MEASURES AND WEIGHTS.

The Metric System of Measures and Weights, owing to its extreme simplicity and the facilities afforded in calculations by its complete decimal character, and consequent freedom from labor in converting one denomination into another, has been adopted by most of the European nations. Its use has also been legalized in the United States, by an Act of Congress, passed July 28, 1866, in which it is provided that "It shall be lawful throughout the United States of America to employ the weights and measures of the metric system; and no contract, or dealing, or pleading in any court shall be deemed invalid or liable to objection because the weights and measures expressed or referred to therein are weights and measures of the metric system."

METRIC MEASURES OF LENGTH.

		Equivalents in English Standard Measures.					
		Inches.	Feet.	Yards.	Rods.	Furlongs.	Miles.
Millimètre	$\frac{1}{1000}$ of a mètre	0.0394					
Centimètre	$\frac{1}{100}$ of a mètre	0.3937					
Decimètre	$\frac{1}{10}$ of a mètre	3.937					
Mètre	Unit of measure	39.37	3.28	1.09			
Decamètre	10 mètres	393.7	32.80	10.94	1.99		
Hectomètre	100 mètres	....	328.	109.37	19.9	.497	
Kilomètre	1,000 mètres	....	3280.	1093.63	199.		.62
Myriamètre	10,000 mètres	....	....	....	....	....	6.21

METRIC MEASURES OF SURFACE.

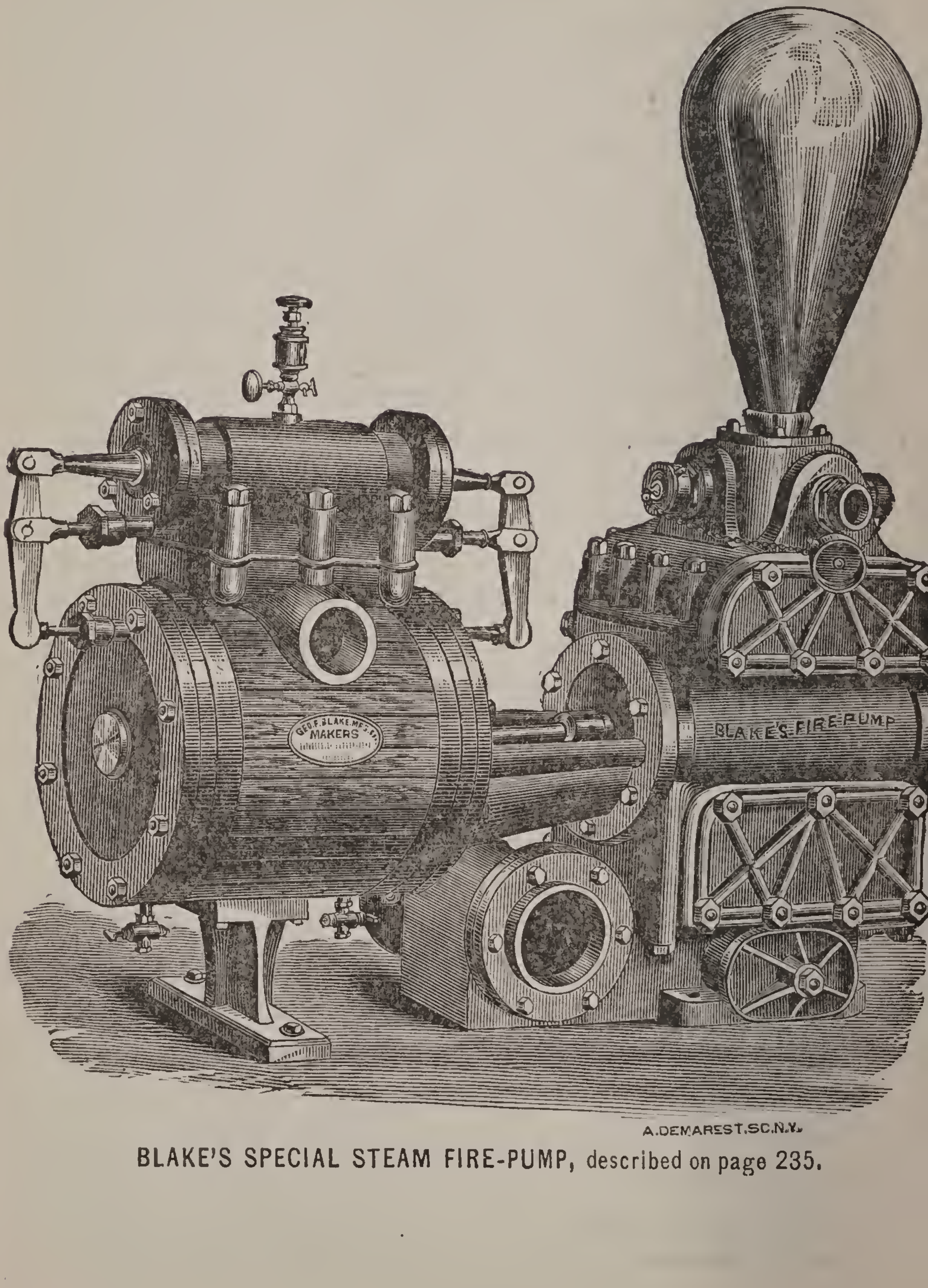
	Equivalent in English Standard Measures.					
	Sq. Inches.	Square Feet.	Square Yds.	Square Poles.	Roods.	Acres.
Square Centimètre	.155					
Square Decimètre	15.50	.107				
Square Mètre	1,550.06	10.76	1.20			
Square Decamètre, or Are	....	....	119.60	3.95	0.099	0.247
Hectare	....	....	11,960.33	395.38	9.88	2.47

METRIC MEASURES OF CAPACITY.

		Dry Measure.		Liquor Measure.			
		Pecks.	Bushels.	Gills.	Pints.	Quarts.	Gallons.
Centilitre	$\frac{1}{100}$ of a litre			.07			
Decilitre	$\frac{1}{10}$ of a litre			.70	.176		
Litre	Unit of capacity				1.76	0.88	0.22
Decalitre	10 litres	1.1					2.20
Hectolitre	100 litres		2.75				22.01

METRIC WEIGHTS.

		Weight or quantity of water at maximum density.	Equiv. in Standard English Weights.		
			Troy Grains.	Avoirdupois Ounces.	Pounds.
Milligramme	$\frac{1}{1000}$ of a gramme	1 millimètre	.0154		
Centigramme	$\frac{1}{100}$ of a gramme	10 millimètres	.1543		
Decigramme	$\frac{1}{10}$ of a gramme	$\frac{1}{10}$ cubic centimètre	1.543		
Gramme	Unit of weight	1 cubic decimètre	15.43		
Decagramme	10 grammes	10 cubic decimètres		.3527	
Hectogramme	100 grammes	100 decimètres		3.527	
Kilogramme	1,000 grammes	1 litre			2.2046
Myriagramme	10,000 grammes	10 litres			22.046
Quintal	100,000 grammes	1 hectolitre			220.46
Millier or Tonneau	1000,000 grammes	1 cubic mètre			2204.6



BLAKE'S SPECIAL STEAM FIRE-PUMP, described on page 235.

PUMPS.

Pumps, whether hand-power or steam, for whatever purpose used, whether for raising liquids or extinguishing fires, should be considered as mere hydraulic machines, placed at one end of a tube or hose, to remove the pressure of the air from the inside of the tube, while the atmosphere is left free to act on the surface of the liquid or fluid in which the other end of the tube is immersed. So far as the accomplishment of this object is concerned, it is immaterial what the shape of the pump-barrel may be, or of what material it is constructed, provided that it is air-tight. The cylindrical form is that most generally adopted; not because it increases the efficiency of the pump, but simply because it offers better advantages for fitting, and consequently can be more economically manufactured than any other. Pumps with square or oval cylinders, if thoroughly fitted, would be just as efficient as those with round cylinders, but they would be more expensive to manufacture and more difficult to repair.

Pumps may be divided into two classes, "lift or suction" and "force;" though some perform the double duty of lifting and forcing. These, again, are divided into several varieties: the "single-acting," "double-acting," "rotary," "centrifugal," "bucket and plunger," and "solid piston." The "single-acting" pump draws or allows the water to enter the barrel at one end of the stroke and forces it out at the other. The "double-acting," as its name implies, forces the water out at each end of the stroke, the water following the piston and filling the barrel as each movement is made, but changing its direction at each stroke to either end of the barrel; one pump of this description is equal to two single-acting pumps of the same capacity.

Rotary pumps, when well constructed, are very effi-

cient, as the water flows in continuously in one direction and out at the other, without change of motion, which induces less loss of power than any other mechanical arrangement. But though theoretically considered, all rotary machines are perfect, yet rotary pumps have never, until quite lately, been able to maintain a permanent place among machines for raising water. This arose from a want of proper facilities and experience to aid in their construction. The great difficulties which have heretofore limited their usefulness and application are now being successfully removed, and Holly's Rotary Pump, used on the Silsby Steam Fire-Engine, is claimed to be one of the most simple, durable, and efficient pumps in the country.

Centrifugal Pumps. — The principle on which the centrifugal pump is based consists, essentially, in the rapid revolution of fans or arms in a scroll, sweeping or whirling the contained air to wherever it may find a vent; the centrifugal momentum acquired in the revolution reacting from the inner walls of the scroll, and resolving itself into a force acting in the direction of the discharge. Heald and Cisco's centrifugal pumps are very efficient for wrecking and mining purposes, or wherever it becomes necessary to displace large bodies of water in a short time. They are very extensively used, both in this country and in Europe.

The Bucket and Plunger Pump.—This class of pumps is extremely simple, both in design and construction. They have but two valves, and possess the same advantages of delivery as double-acting pumps. The water is received only on the upward stroke, the amount being equal to the full capacity of the cylinder. Only one-half, however, is discharged, owing to the smaller area of the upper side of the piston. On the downward stroke, the water in the cylinder is forced out by the piston — one-

half being discharged, the other half flowing into the upper end of the cylinder. Wright's Double-acting Bucket-plunger Pump, manufactured by the Valley Machine Co., Easthampton, Mass., is one of the most simple and efficient pumps in use.

Solid Piston-Pumps. — This is the most ancient of all pumps, and it was extensively used in Egypt 500 years B.C. The capacity of a piston-pump is its area multiplied by the length of its stroke; but it must be remembered that all pumps throw less water than their theoretic capacity would indicate. Consequently, the piston-pump is often condemned for no other reason than that there are a great many poor ones manufactured, which, as a matter of course, does not at all affect the principle involved in the working of such pumps.

Atmospheric "lift" or "suction" pumps cause the water to raise itself by having its surface relieved of the column of air resting upon it.* If, therefore, one end of a pipe or tube be lowered into water, the other end closed by means of a valve or other device, and the air contained in the pipe be drawn out, it is evident that the surface of the water within the pipe will be relieved of the pressure of the atmosphere. There will then be no resistance offered to the water to prevent its rising in the tube. The water outside of the pipe, still having the pressure of the atmosphere upon its surface, therefore forces water up into the pipe, supplying the place of the excluded air, while the water inside the pipe will rise above the level of that outside of it proportionally to the extent to which it is relieved of the pressure of the air; so that, if the first

* The idea entertained by many that water is raised by suction, is erroneous, as, properly speaking, there is no such principle as suction. Water or other liquids are raised through a tube or hose by having the pressure of the atmosphere removed from their surface.

stroke of a pump reduce the pressure of the air contained in the pipe from 15 pounds on the square inch (which is its normal pressure) to 14 pounds, the water will be forced up the pipe to the distance of about $2\frac{1}{4}$ feet, since a column of water an inch square and $2\frac{1}{4}$ feet high is equal to about 1 pound in weight.

It is evident that, upon the reduction of the pressure of the air contained in the pipe from 15 to 14 pounds per square inch, there would be (unless the water ascended the pipe) an unequal pressure upon its surface inside, as compared to that outside of the pipe; but in consequence of the water rising $2\frac{1}{4}$ feet in the pipe, the pressure on the surface of the water, both inside and outside, is evenly balanced (taking the level of the outside water to be the natural level of the water inside), as the pressure upon the water exposed to the full atmosphere is 15 pounds upon each square inch of its surface, while that upon the same plane, but within the pipe, will sustain a column of water $2\frac{1}{4}$ feet high (weighing 1 pound) and 14 pounds pressure of air, making a total of 15 pounds, which is, therefore, an equilibrium of pressure over the whole surface of the water at its natural level.

If, in consequence of a second stroke of the pump, the air-pressure in the pipe is reduced to 13 pounds per inch, the water will rise another $2\frac{1}{4}$ feet. This rule is uniform, and shows that the rise of a column of water within the pipe is equal in weight to the pressure of the air upon the surface of the water without; hence it is only necessary to determine the height of a column of water that will weigh 15 pounds per square inch of area at the base, to ascertain how far a suction-pump will cause water to rise.

But it must be remembered that the distance varies with the height above sea level, and also with the pressure of the atmosphere. At our level of the sea, the column

of water that the atmosphere will support is about 33 feet in height, and a pump will "draw water," as it is called, this distance; but the force which sends the water into the pump at this height is so diminished as to be almost balanced by its own weight; hence a lifting pump would deliver water very slowly, drawing it this distance. To be perfectly reliable, the cylinder and piston should be in good order, all the joints perfectly air-tight, a check-valve be placed in the lower end of the suction-pipe; and even then the pump should be run at a high speed. Pumps will give more satisfactory results when the lift is from 22 to 25 feet. There is hardly any limit to the distance a pump will draw water through a horizontal suction-pipe, provided the pipe is perfectly tight, and everything is so proportioned as not to cause undue friction.

The great trouble with long pump-pipes is the difficulty of getting them perfectly tight; cast connections sometimes contain small sand holes, and screw connections are often imperfect; in fact, all long suction-pipes, especially where the lift is high, are apt to leak, which of course interferes with the efficiency of the pump.

Force-pumps are those by means of which the water is expelled from the pump-barrel, and through the delivery-pipe by means of the mechanical force applied to the pump-piston or plunger; the amount of power required to drive such a pump will, therefore, depend at all times upon the height to which the water is required to be forced. When a pump is arranged to draw the water, and force it after it has left the pump-barrel, it is termed a lift- and force-pump; but if the water merely flows into it in consequence of the level of the water-supply being equal to or above that of the top of the pump-barrel, it is termed simply a force-pump. Hence a suction-pump performs its

duty in causing the water to rise to the pump; a force-pump is one which performs its duty in expelling water from its barrel; and a suction- and force-pump is one which performs both duties alternately.

No pump will lift very hot water, for the reason that, the atmospheric pressure being removed, it passes in vapor through the suction-pipe, and fills the cylinder with steam instead of water, so that on the return-stroke, the piston, meeting with no resistance, moves rapidly, until, suddenly striking the water which partially fills the cylinder, a violent concussion is produced, which is very injurious to the pump and its connections. Therefore, for pumping hot liquids, the point of supply should not be below the pump, but if possible a little above it, so that the liquid may flow into it.

The capacity of any pump can be easily determined, if its dimensions are known, by multiplying the area of the piston in inches by its stroke in inches, giving the number of cubic inches per single stroke; this, divided by 231 (the number of cubic inches in a standard gallon), will give the number of gallons per single stroke; but it must be remembered that all pumps throw less water than their capacity, the deficiency ranging from 20 to 40 per cent., according to the quality of the pump. This loss arises from the lift and fall of the valves, from inaccuracy of fit or leakage, and in many cases from there being too much space between the valves and piston, or plunger. The higher the valves of any pump have to lift to give the necessary opening, the less efficient the pump will be.

The power required to raise a given quantity of water a certain height can be easily computed by the following rule: Multiply the amount of water in gallons to be raised per minute by 8.35, (the weight of a gallon of water,) and this product by the height, in feet, of the discharge from

the point of suction; divide the result by 33,000, which will give the theoretical horse-power required to raise the amount of water a certain distance. But from this result there should be an allowance made of from 10 to 30 per cent., for loss induced from leakage in the pipes, short bends, bad condition of the pump, friction of water in the pipes, friction of the parts of the pump in contact, etc.

STEAM-PUMPS.

Steam-pumps may be said to be among the most essential requisites of the age, and the competition which exists in their manufacture is something wonderful. The machine market is full to overflowing with pumps of different patterns, and adapted to almost every variety of purpose; this arises from the fact that in a great many locations where power has to be employed in raising water, steam is the only power which can be conveniently applied. It is suitable for almost any situation, is easily managed, is generally understood by mechanics, and presents no difficulties not easily overcome. Its universal adaptability, and the immense demand for steam-driven pumps, have turned the attention of engineers and capitalists in this direction, and at the present time the manufacture of steam-pumps and their accessories ranks as one of the most extensive industries in the country.

It is interesting to note the fact, that James Watt, the so-called father of the steam-engine, was really a steam-pump man, all his engines for a great many years being devoted entirely to the pumping of water out of mines. The application of the steam-engine to the furnishing of power for other purposes was carried out by others. In Watt's time, however, pumps worked by steam were cumbersome, expensive, and unreliable; but the manufacturers

of the present day have so simplified and cheapened them, that while their cost is very small, their management is so simple that they may be said to be perfectly automatic.

The following are the names of the pumps most generally employed in manufacturing, mining, and mechanical engineering: Boiler feed-pumps, tank or light service pumps, special fire-pumps, mining pumps, tannery pumps, brewer's mash- and beer- pumps, brewer's water- and air-pumps, marine bilge- and fire-pumps, marine air-pumps, wrecking pumps, oil-refinery pumps, oil line-pumps, sugar-house pumps, plantation pumps, vacuum pumps, locomotive pumps, plunger pumps, hydraulic pumps, combined boiler and pump, low-pressure pump, air-pumps, acid pumps, gas-works pumps, lard or soap pumps, bleachery pumps, drainage and irrigating pumps, vinegar pumps, quarry pumps, and marine circulating pumps. This latter class, particularly the "Blake," is rapidly gaining favor, as, in consequence of being independent of the main engines, they can be run at any desirable speed, and furnish a great safeguard against foundering at sea in case of accident to the main engines. If the pumps were attached to the main engines, the same weight of water could be discharged overboard, provided that engines could be run at the proper speed; but it must be remembered that it takes the whole power of the boilers to run the engines at the ordinary speed, and that their speed cannot be increased in an emergency. Oftentimes, by reducing the speed of the main engines, the independent circulating pump can be kept at its maximum, hence its great advantage. No ocean steamer, lake or river boat can be considered safe, unless it has on board one or two reliable independent steam-pumps. They are as indispensable for marine purposes as life-boats.

As boiler feeders, steam-pumps are superior to any other known device, being capable of forcing water against

the most extreme pressures, and of supplying boilers when circumstances require the stoppage of the engine. They may be regulated to furnish either a constant supply or a great quantity of water in a short time; but as fire-extinguishers, they are indispensable, as, with a good supply of water, and a steam-pump of sufficient power and capacity to force it to a great height or distance, there can be no reason why almost any fire cannot be held in check, or even extinguished, without the aid of a steam fire-engine. Millions of dollars' worth of valuable property are destroyed every year, which might have been saved by the judicious investment of a few thousands in reliable steam-pumps. Their great value as a means of extinguishing fire and preventing the destruction of valuable property is beginning to be universally appreciated.

BLAKE'S SPECIAL STEAM FIRE-PUMP.

The cut on page 226 represents Blake's Special Steam Fire-pump.—This pump has two steam-valves, viz., a main and an auxiliary, both of which are plain, flat slide-valves, the same as used in the simple steam-engine. The main valve is placed in such a position as to be driven by an ordinary spring-ring steam-piston, that becomes necessarily as positive in action as any steam-piston when exposed to pressure, being a common D valve controlling the ordinary three-ported steam-engine.

The auxiliary valve is a plain, flat slide-valve attached to a valve-rod, which receives an impulse from the main steam-piston; it is therefore moved with the same degree of certainty that an eccentric moves the slide-valve of an ordinary steam-engine; this is a B valve. The movable seat is a casting forming the auxiliary valve, which has three ports, coinciding in every position with the three

ports of the main engine, thus forming an upward extension of the engine ports, on the upper seat of which the main valve takes its position.

If the main piston attains a velocity exceeding that of the piston which drives the valve, it would certainly strike the cylinder-head. The movable seat makes such an impact an impossibility; since, having a mechanical connection with the valve-rod, it is brought into such position as to become the main valve, independent of the action of the main valve proper, and gives direct steam to cushion and reverse the engine.

The pressure of a small cylinder surmounting the main cylinder must not be confounded with that generally used. This cylinder is for the purpose of containing an ordinary spring-ring steam-piston — not a valve — which is the motor for the main valve. The main and auxiliary valves are merely flat, plain surfaces, and their respective positions being face to face, the wear is consequently even, as well as compensating, precisely the same as with any plain steam-engine valve.

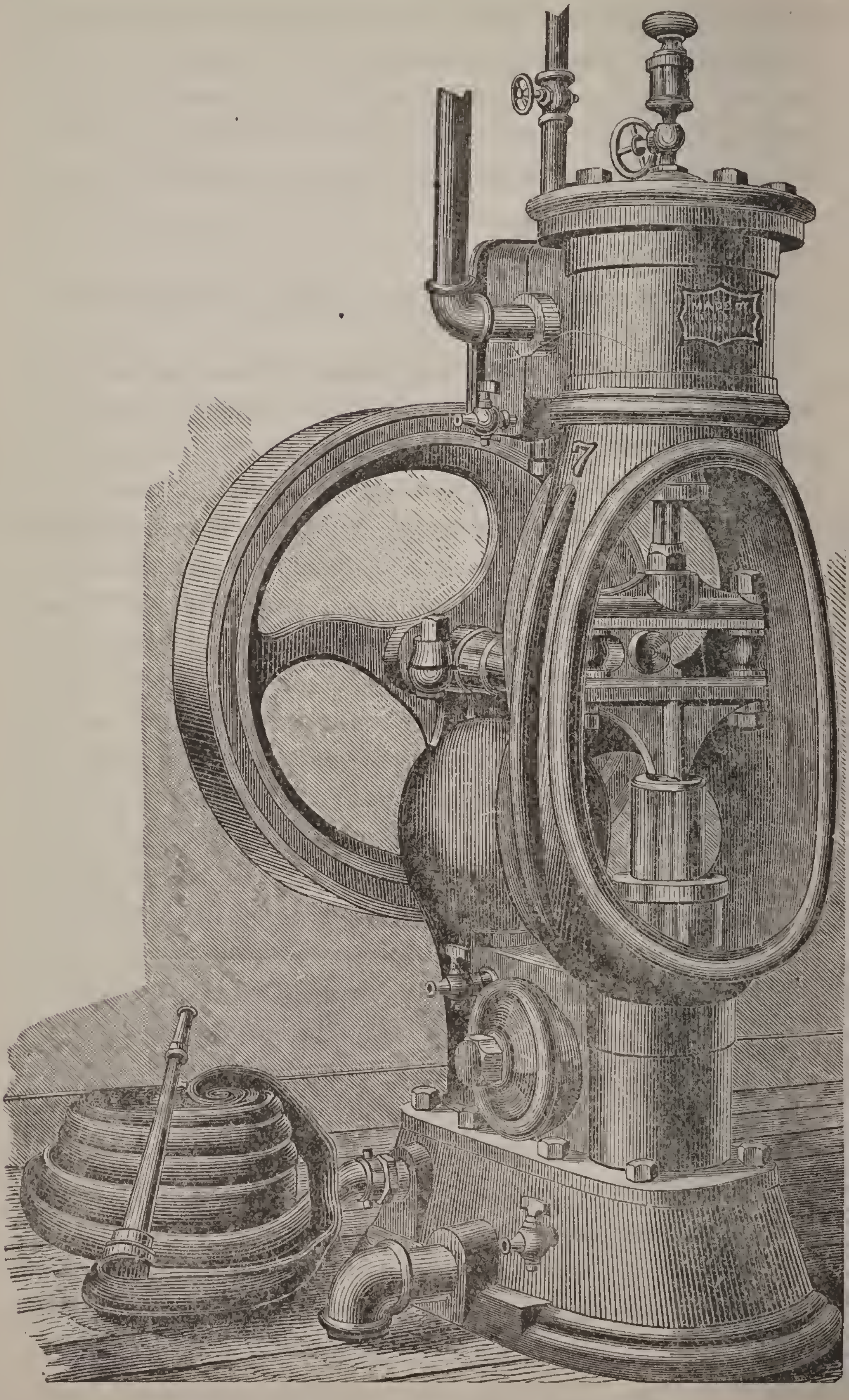
The pistons are made with adjustable spring-rings, and compensate for wear, and are so arranged as to permit the packing-rings in the cylinder to revolve, which renders the wear more uniform than if the rings were stationary. The stuffing-boxes are made of the best composition, which prevents the possibility of waste, either by high temperatures or corrosion. All the parts are made sufficiently strong to withstand the heaviest concussion to which a pump can be subjected; but, in the event of the breakage of any of the parts resulting from accident, as the parts are all made to standard gauges, they can be duplicated by simply writing to the factory or warehouse. The Blake Fire-pump is one of the most powerful, efficient, and durable pumps in the country; it is symmetrical in design,

simple in construction, and is so arranged that any of the pieces can be disengaged without disturbing any part of the pump. They are manufactured in sizes ranging from 8 in. diameter of steam-cylinder, 5 in. diameter of water-cylinder to 24 in. diameter of steam-cylinder, 12 in. diameter of water-cylinder.

WRIGHT'S BUCKET-PLUNGER STEAM FIRE-PUMP.

The cut on the following page represents Wright's Vertical Bucket-plunger Steam Fire-pump. The steam-cylinder rests on an open, upright, circular frame. The cylinder and frame constitute one solid casting (except in the larger sizes); the pedestal of the latter is firmly bolted to an oval base, which contains the suction and discharge openings of the pump. The crank-shaft and crank-pin are made from one solid piece of steel, the eccentric being firmly keyed to the latter, preventing the possibility of any derangement of the valve motion, while the opening in the front of the upright frame affords easy facility for packing the steam- and water-piston, or for the adjustment of the yoke motion. The water-valves are simply circular pieces of metal, rubber, or leather, rising on a stem which is fastened to the valve-seats, access to them being obtained through openings on either side of the pump by simply unscrewing two nuts. The packing-rings in the water-plunger are made of gun-metal, the inside ring being made thinnest at the cut, thus giving more elasticity with less friction. Leather packing may be used instead of the rings, if preferred, or a solid bronze metal end may be used instead of either.

The water-valves can be removed by simply unscrewing two nuts and withdrawing the wedge that rests on the discharge-valve stem, the suction-valves being directly



WRIGHT'S BUCKET-PLUNGER STEAM FIRE-PUMP.

under the discharge-valves in the base of the pump. Rubber valves can be substituted for metal, or *vice versa*, without a change of valve-seats. The steam-valve is properly "set" and the eccentric keyed on the shaft. The best quality of steel is used for the valve-stems and piston-rods. Brass is used for stuffing-box glands and nuts and genuine Babbitt mixture in the shaft bearings. The shaft, crank, and crank-pin form one continuous wrought-iron forging.

The manufacturers of this pump claim, that, as very little of the power of the engine of a steam-pump is expended in getting the water into the cylinder through the suction-valves, but is nearly all used in forcing it out, they gain a great advantage by making the water-cylinder twice the area of ordinary double-acting steam-pumps; they also dispense with one-half the number of water-valves, as the quantity discharged on the upper stroke is thrown out through an opening in the top of the pump cylinder, and does not pass through them. These pumps are very simple in design and construction, and have the reputation of being very durable and efficient.

DIMENSIONS OF THE BUCKET-PLUNGER STEAM FIRE-PUMPS.

Diameter of Steam Cylinder in Inches.	Diameter of Water Plunger in Inches.	Revolutions per Minute, varying with kind of work and pressure.	Displacement in Gallons per Revolut'n.	Diameter of Steam Cylinder in Inches.	Diameter of Water Plunger in Inches.	Revolutions per Minute, varying with kind of work and pressure.	Displacement in Gallons per Revolut'n.
4	$2\frac{1}{4}$	50 to 200	$\frac{4}{100}$	10	$6\frac{1}{2}$	30 to 150	$\frac{54}{100}$
5	$2\frac{3}{4}$	50 to 200	$\frac{7}{100}$	10	7	25 to 125	$\frac{91}{100}$
$5\frac{3}{4}$	$3\frac{1}{2}$	40 to 175	$\frac{10}{100}$	12	8	25 to 125	$1\frac{30}{100}$
7	$4\frac{1}{4}$	40 to 175	$\frac{18}{100}$	14	10	25 to 125	$2\frac{4}{100}$
8	$5\frac{1}{4}$	30 to 150	$\frac{38}{100}$				

PROPORTIONS OF STEAM FIRE-PUMPS.

Diam. Steam Cyl. in Inches.	Diam. Water Cyl. in Inches.	Stroke in Inches.	Gallons per Stroke.	Steam Pipe in Inches.	Exha'st Pipe in Inches.	Suction Pipe in Inches.	Discharge Pipe in Inches.
8	5	12	1.02	1	1½	3½	3
10	5	12	1.02	1¼	2	3½	3
10	6	12	1.47	1¼	2	3½	3
12	6	12	1.47	1½	2½	3½	3
12	7	12	2.00	1½	2½	4	3
14	7	12	2.00	2	3	4	two 3
14	8	12	2.61	2	3	5	" 3
16	8	18	3.92	2	3	6	" 4
16	9	18	4.96	2	3	6	" 4
18	9	24	6.60	2	3	8	four 3
18	10	24	8.16	2	3	8	" 3
20	10	24	8.16	2½	3½	8	" 3
20	12	24	11.75	2½	3½	8	" 3

PROPORTIONS OF BOILER FEED-PUMPS.

Diameter Steam Cylinder in Inches.	Diam. Water Cylinder in Inches.	Length of Stroke in Inches.	Gallons per Stroke.	Steam Pipe in Inches.	Exha'st Pipe in Inches.	Suction Pipe in Inches.	Discharge Pipe in Inches.
4	2½	3½	.07	½	¾	1	¾
4	2½	5	.11	½	¾	1¼	1
5½	3¼	7	.25	½	¾	1½	1¼
6	3¾	7	.33	¾	1	2	1½
7¼	4½	10	.69	1	1½	2½	2
8	5	10	.85	1	1½	3	2½
8	5	12	1.02	1	1½	3½	3
10	6	12	1.47	1¼	2	3½	3
12	7	12	2.00	1½	2½	4	3
14	8	12	2.61	2	3	5	3½
16	9	18	4.96	2	3	6	4
18	12	24	11.75	2	3	8	6
20	14	24	16.00	2½	3½	10	8

PROPORTIONS OF MARINE-PUMPS.

Steam Cylinder in Inches.	Water Cylinder in Inches.	Stroke in Inches.	Gallons per Stroke.	Steam Pipe in Inches.	Exhas't Pipe in Inches.	Suction Pipe in Inches.	Dischg'e Pipe in Inches.
6	$3\frac{3}{4}$	7	.33	$\frac{3}{4}$	1	2	$1\frac{1}{2}$
$7\frac{1}{4}$	$4\frac{1}{2}$	10	.69	1	$1\frac{1}{2}$	$2\frac{1}{2}$	2
$7\frac{1}{4}$	7	10	1.66	1	$1\frac{1}{2}$	4	3
8	5	12	1.02	1	$1\frac{1}{2}$	$3\frac{1}{2}$	3
8	8	12	2.61	1	$1\frac{1}{2}$	5	$3\frac{1}{2}$
10	6	12	1.47	$1\frac{1}{4}$	2	$3\frac{1}{2}$	3
10	10	12	4.08	$1\frac{1}{4}$	2	5	$3\frac{1}{2}$
10	12	12	5.87	$1\frac{1}{4}$	2	8	6
12	7	12	2.00	$1\frac{1}{2}$	$2\frac{1}{2}$	4	3
12	12	12	5.87	$1\frac{1}{2}$	$2\frac{1}{2}$	8	6
12	12	18	8.80	$1\frac{1}{2}$	$2\frac{1}{2}$	8	6
12	14	18	12.00	$1\frac{1}{2}$	$2\frac{1}{2}$	8	6
14	8	12	2.61	2	3	5	$3\frac{1}{2}$
14	12	18	8.80	2	3	8	6
14	14	18	12.00	2	3	8	6
16	9	18	4.96	2	3	6	4
16	14	18	12.00	2	3	8	6
16	14	24	16.00	2	3	10	8
16	16	24	20.89				
18	18	20	22.03				
20	20	24	32.64				

PROPORTIONS OF WRECKING-PUMPS.

Steam Cylinder in Inches.	Water Cylinder in Inches.	Stroke in Inches.	Steam Pipe in Inches.	Exhaust Pipe in Inches.	Suction Pipe in Inches.	Discharge Pipe in Inches.
8	14	10	1	$1\frac{1}{2}$	8	7
8	10	12	1	$1\frac{1}{2}$	5	$3\frac{1}{2}$
8	12	12	1	$1\frac{1}{2}$	8	6
10	12	12	$1\frac{1}{4}$	2	8	6
10	14	12	$1\frac{1}{4}$	2	8	6
12	14	18	$1\frac{1}{2}$	2	8	6
14	16	18	2	3	12	10
14	18	18	2	3	14	12
16	20	24				
18	24	24				
20	30	24				

PROPORTIONS OF MINING-PUMPS.

Steam Cyl. in Inches.	Water Cyl. or Plunger in Ins.	Stroke in Ins.	Gallons per Stroke.	Steam Pipe in Ins.	Exha'st Pipe in Ins.	Suction Pipe in Ins.	Disch. Pipe in Ins.
8	5	12	1.02	1	1½	3½	3
10	5	12	1.02	1¼	2	3½	3
10	6	12	1.47	1¼	2	3½	3
12	6	12	1.47	1½	2½	3½	3
12	7	12	2.00	1½	2½	4	3
14	7	12	2.00	2	3	4	3
14	8	12	2.61	2	3	5	3½
14	8	18	3.92	2	3	6	4
16	8	18	3.92	2	3	6	4
16	9	18	4.96	2	3	6	4
16	9	24	6.60	2	3	8	6
18	9	18	4.96	2	3	6	4
18	9	24	6.60	2	3	8	6
18	10	24	8.16	2	3	8	6
18	10	36	12.24	2	3	8	6
20	10	24	8.16	2½	3½	8	6
20	10	36	12.24	2½	3½	8	6
20	12	24	11.75	2½	3½	10	8
24	12	36	17.63	3	4	10	8
24	14	24	16.00	3	4	12	10
24	14	36	24.00	3	4	12	10
30	12	36	17.63	4	6	10	8
30	14	36	24.00	4	6	12	10
30	16	50	43.50	4	6	14	12

PROPORTIONS OF AIR-PUMPS.

Diam. Steam Cyl. in Ins.	Diam. Air Cyl. in Ins.	Length of Stroke in Ins.	Cubic feet of Air per Stroke.	Size of Steam Pipe.	Size of Exha'st Pipe.	Size of Suction.	Size of Disch.
5	10	6	.27	½	¾	According to duty.	According to duty.
5	15	6	.66	½	¾		
7	20	9	1.63	¾	1¼		
10	12	16	1.05	1¼	1½		
10	20	16	2.90	1¼	1½		
10	30	16	6.54	1¼	2		
10	30	36	14.72	1¼	2		
14	30	16	6.54	2	2½		
12	30	36	14.72	1¼	2		
14	30	36	14.72	2	2½		
16	30	36	14.72	2	2½		
18	48	48	45.52	2½	3		
24	72	72	169.64	3	4		
37	84	120					

PROPORTIONS OF TANK-PUMPS.

Diam. of Steam Cyl. in Ins.	Diam. of Water Cyl. in Ins.	Length of Stroke in Ins.	Gallons per Stroke.	Size of Steam Pipe.	Size of Exha'st Pipe.	Size of Suction.	Size of Dis-charge.
4	4	5	.27	$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	1
$5\frac{1}{2}$	$5\frac{1}{2}$	6	.62	$\frac{3}{4}$	1	3	2
$7\frac{1}{2}$	$7\frac{1}{2}$	9	1.72	$\frac{3}{4}$	$1\frac{1}{4}$	4	3
8	8	12	2.61	1	$1\frac{1}{4}$	5	5
10	10	16	5.43	$1\frac{1}{4}$	$1\frac{1}{2}$	6	4
10	12	16	7.83	$1\frac{1}{4}$	$2\frac{1}{2}$	8	6
12	12	16	7.83	2	$2\frac{1}{2}$	8	6
14	12	24	11.75	2	$2\frac{1}{2}$	8	6
14	14	24	15.99	2	$2\frac{1}{2}$	10	8
14	18	24	26.43	2	$2\frac{1}{2}$	12	10
16	18	24	26.43	$2\frac{1}{2}$	3	12	10
14	22	24	39.49	$2\frac{1}{2}$	3	14	12
16	16	24	20.80	$2\frac{1}{2}$	3	12	10
18	12	24	11.75	$2\frac{1}{2}$	3	8	6
18	14	24	15.99	$2\frac{1}{2}$	3	10	8
18	18	24	26.43	$2\frac{1}{2}$	3	12	10
18	22	24	39.49	$2\frac{1}{2}$	3	14	12
18	42	24	47.	$2\frac{1}{2}$	3	16	14

PROPORTIONS OF BREWERS' AND DISTILLERS' PUMPS.

Diameter Steam Cylinder in Ins.	Diam. Water Cyl. in Ins.	Length of Stroke in Ins.	Gallons per Stroke.	Size of Steam Pipe.	Size of Exha'st Pipe.	Size of Suction.	Size of Dis-charge.
$5\frac{1}{2}$	$5\frac{1}{2}$	6	.62	$\frac{3}{4}$	1	3	2
7	5	10	.75	1	$1\frac{1}{4}$	3	$2\frac{1}{2}$
$7\frac{1}{2}$	$7\frac{1}{2}$	9	1.72	$\frac{3}{4}$	$1\frac{1}{4}$	4	3
8	8	12	2.61	1	$1\frac{1}{4}$	5	$3\frac{1}{2}$
10	8	12	2.61	$1\frac{1}{4}$	$1\frac{1}{4}$	5	$3\frac{1}{2}$
10	10	16	5.43	$1\frac{1}{4}$	$1\frac{1}{2}$	6	4
12	10	16	5.43	2	$2\frac{1}{2}$	6	4
14	10	16	5.43	2	$2\frac{1}{2}$	6	4
14	12	24	11.75	2	$2\frac{1}{2}$	8	4

TABLE

SHOWING THE PROPORTIONS OF STEAM-PUMPS DEMONSTRATED BY PRACTICAL EXPERIENCE TO BE THE BEST ADAPTED FOR THE VARIOUS PURPOSES FOR WHICH THEY ARE USED.

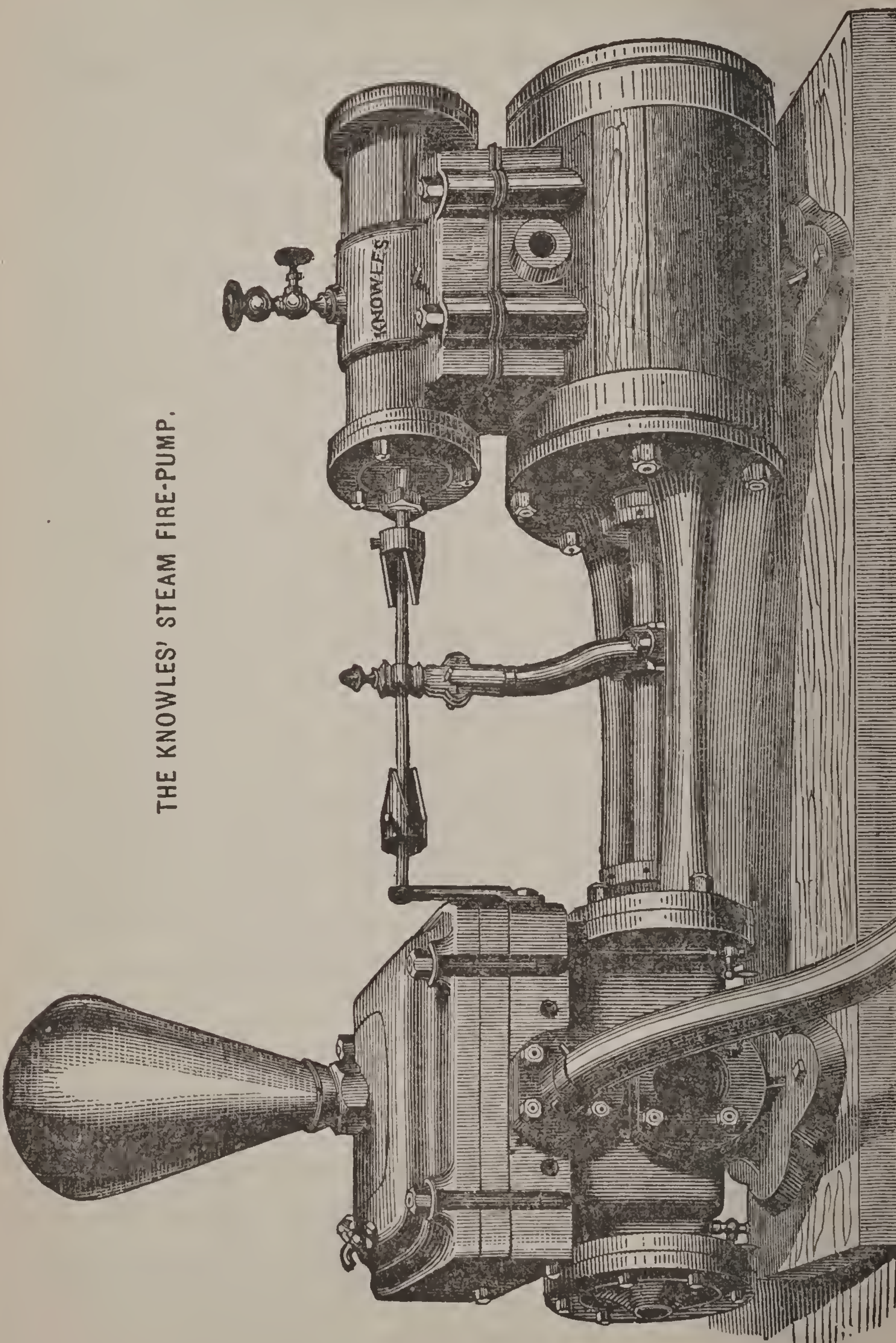
Steam Cylinder in Inches.	Water Cylinder in Inches.	Exhaust Pipe in Inches.	Suction Pipe in Inches.	Discharge Pipe in Inches.
4	2½	¾	1	¾
4	1¼	¾	1¼	1
4	2½	¾	1¼	1
4	4	¾	1½	1¼
5½	2	¾	1½	1¼
5½	2½	¾	1½	1¼
5½	3¼	¾	1½	1¼
5½	3¾	¾	2	1½
5½	4½	¾	2½	2
5½	5½	¾	2½	2
6	2½	1	1½	1¼
6	3	1	1½	1¼
6	3¼	1	1½	1¼
6	3¾	1	2	1½
6	4½	1	2½	2
6	5½	1	3	2
7¼	3	1½	2½	2
7¼	3¾	1½	1½	2
7¼	4½	1½	2½	2
7¼	5	1½	3	2½
7¼	7	1½	4	3
8	3¾	1½	2½	2
8	4½	1½	2½	2
8	5	1½	3	2½
8	14	1½	8	7
8	5	1½	3½	3
8	6	1½	3½	3
8	7	1½	4	3
8	8	1½	5	3½
8	10	1½	5	3½
8	10	1½	6	4
8	12	1½	8	6
8	12	2	8	6
10	4	2	3	2
10	5	2	3½	3

Steam Cylinder in Inches.	Water Cylinder in Inches.	Exhaust Pipe in Inches.	Suction Pipe in Inches.	Discharge Pipe in Inches.
10	6	2	3½	3
10	7	2	4	3
10	8	2	5	3½
10	9	2	6	4
10	10	2	5	3½
10	10	2	8	6
10	12	2	8	6
10	12	2	8	6
12	4½	2½	3½	3
12	5	2½	3½	3
12	6	2½	3½	3
12	7	2½	4	3
12	8	2½	5	3½
12	9	2½	6	4
12	10	2½	5	3½
12	10	2½	8	6
12	12	2½	8	6
12	12	2½	8	6
12	14	2½	8	6
12	16	2½	12	10
12	18	2½	14	12
14	4	3	3	2
14	4	3	3	2
14	5	3	3½	3
14	5	3	3½	3
14	6	3	3½	3
14	7	3	4	3
14	7	3	4	3
14	8	3	5	3½
14	8	3	6	4
14	9	3	6	4
14	10	3	5	3½
14	10	3	8	6
14	12	3	8	6
14	12	3	8	6
14	14	3	8	6
14	16	3	12	10
14	18	3	14	12

TABLE—(*Continued.*)

Steam Cyl. in In.	Water Cyl. in In.	Steam Pipe in In.	Exhaust Pipe in In.	Suction Pipe in In.	Discharge Pipe in In.
14⅝	9	2	3	6	4
14⅝	10	2	3	8	6
14⅝	12	2	3	8	6
14⅝	14	2	3	10	8
14⅝	15	2	3	10	8
16	5	2	3	3½	3
16	7	2	3	4	3
16	8	2	3	6	4
16	9	2	3	6	4
16	9	2	3	8	6
16	10	2	3	8	6
16	10	2	3	8	6
16	12	2	3	8	6
16	12	2	3	8	6
16	14	2	3	8	6
16	14	2	3	10	8
16	14	2	3	10	8
16	15	2	3	10	8
16	16	2	3	12	10
16	18	2	3	14	12
16	20	2	3		
16	24	2	3		
18	5	2	3	3½	2
18	8	2	3	6	4
18	9	2	3	6	4
18	10	2	3	8	6
18	10	2	3	8	6
18	10	2	3	8	6
18	12	2	3	8	6
18	12	2	3	8	6
18	12	2	3	8	6
18	14	2	3	8	6
18	14	2	3	10	8
18	14	2	3	10	8
18	15	2	3	10	8
18	15	2	3	10	8
18	18	2	3		

Steam Cyl. in In.	Water Cyl. in In.	Steam Pipe in In.	Exhaust Pipe in In.	Suction Pipe in In.	Discharge Pipe in In.
18	20	2	3		
18	24	2	3		
18	30	2	3		
20	7	2½	3½	4	3
20	9	2½	3½	6	4
20	10	2½	3½	8	6
20	10	2½	3½	8	6
20	12	2½	3½	8	6
20	12	2½	3½	8	6
20	14	2½	3½	8	6
20	14	2½	3½	10	8
20	14	2½	3½	10	8
20	15	2½	3½	10	8
20	15	2½	3½	10	8
20	20	2½	3½		
20	24	2½	3½		
20	30	2½	3½		
24	9	3	4	6	4
24	10	3	4	8	6
24	10	3	4	8	6
24	12	3	4	8	6
24	12	3	4	8	6
24	14	3	4	10	8
24	14	3	4	10	8
24	15	3	4	10	8
24	18	3	4		
24	20	3	4		
24	24	3	4		
24	30	3	4		
30	10	4	6	8	6
30	12	4	6	8	6
30	14	4	6	10	8
30	14	4	6	12	10
30	16	4	6	14	12
30	16	4	6	14	12
30	18	4	6		
30	24	4	6		



THE KNOWLES' STEAM FIRE-PUMP.

THE KNOWLES' STEAM FIRE-PUMP.

The cut on opposite page represents the Knowles' Steam Fire-Pump. The steam-cylinders are fitted with spring packing, which is so arranged as to be easy of adjustment. The water-cylinders are also fitted with composition heads and adjustable rings. The main steam-valve is an ordinary flat slide-valve, and the slight rotary motion given the valve-rod simply puts the valve in a position to be driven horizontally on its seat. This style of flat valve embodies the most favorable possible condition for tightness, even after the wear consequent upon long use. Owing to the peculiar motion of this description of steam-valve, the pumps will start at a moment's notice, by simply opening the steam-valve; and when running at the highest speed, or when the pressure is suddenly removed, the piston can never strike the cylinder-heads. Another peculiarity of this pump is, that it can be used for any ordinary work, and still have the hose always attached to it ready for use, and can be run so slow as to be used as a boiler-feeder, or at great speed as a fire-pump. The Knowles' steam-pumps are built of the best material and fitted in the most thorough manner — the joints are all ground, and require no packing, and, as the parts are all interchangeable, they can, in case of wear or accident, be supplied at short notice. The reputation of the Knowles' steam-pump stands deservedly high for durability, efficiency, and economy. They are manufactured of all desirable sizes, and arranged for an almost endless variety of purposes.

Rule for finding the Diameter of Pump-plunger for any Engine.—When the pump-stroke is $\frac{1}{2}$ the stroke of the engine, the diameter of the steam-cylinder multiplied by 0.3 will give the proper diameter of pump-plunger.

Another Rule.—When the pump-stroke is $\frac{1}{4}$ the stroke

of the engine, the diameter of the cylinder multiplied by .42 will give the proper diameter of pump-plunger.

Diameter of pump-plunger should be equal to $\frac{1}{3}$ the diameter of the cylinder, when the pump-stroke is $\frac{1}{2}$ the engine-stroke.

Diameter of pump-plunger should be equal to $\frac{1}{6}$ of the diameter of the cylinder, when the pump-stroke is $\frac{1}{4}$ the engine-stroke. The velocity of water in pump passages should not exceed 500 feet per minute. Pump-valves should have an area of $\frac{1}{4}$ the area of the pump.

Feed-pumps for Condensing Engines.—For condensing engines, the diameter of the pump-plunger should equal 1.11 the diameter of the steam-cylinder, when the pump-stroke is $\frac{1}{2}$ the engine-stroke, and $\frac{1}{8}$ the diameter of steam-cylinder, when the pump-stroke is $\frac{1}{4}$ the stroke of the engine.

Rule for finding the Necessary Quantity of Water per Minute for any Engine.—Multiply the cubic space in cylinder in inches, to which steam is admitted before being cut off, by twice the number of revolutions per minute, and divide the product by the comparative bulk of steam* at the pressure used; the quotient will be the cubic inches of water required per minute.

EXAMPLE.

Diameter of cylinder, 12 inches. Area....................	113.09 sq. in.
Stroke, 24 in. Steam cut-off at $\frac{1}{2}$ stroke..................	12 in.
Revolutions per minute..	60
Pressure per sq. in., 70 lbs. Cubic in. steam from 1 to $\frac{3}{4}$ cu. in. water..	408

$$\begin{array}{r} 113.09 \\ 12 \\ \hline 1357.08 \\ 120 \\ \hline 408)\underline{162849.60} \\ 399.14 \end{array}$$

399.14 cubic inches of water.

* See Table on pages 338, 339.

This Rule takes into account the expenditure of steam only; but, as it is well known in practice that a large quantity of water passes from the boiler to the cylinder in mechanical combination with the steam, allowance must be made for such losses, also for the waste incurred by clearance in the cylinder, cubic contents of steam-ports, condensation, etc., so that in the selection of a pump for any engine, it is advisable that it should be of sufficient capacity to furnish at least twice the quantity of water designated by the rule.

Pumps too large or too small are not as economical as those that are well proportioned to their work; nevertheless, in ordering or purchasing a pump, it is always better to err on the side of too much capacity than too little. All boiler feed-pumps, when working at ordinary speed, should be capable of discharging one cubic foot of water per horse-power per hour.

Parties ordering pumps should always embody the following information in their orders, as a neglect to do so is frequently attended with a great deal of dissatisfaction and disappointment both to manufacturers and purchasers:

Whether the pump is for hot or cold water.

For high or low pressure.

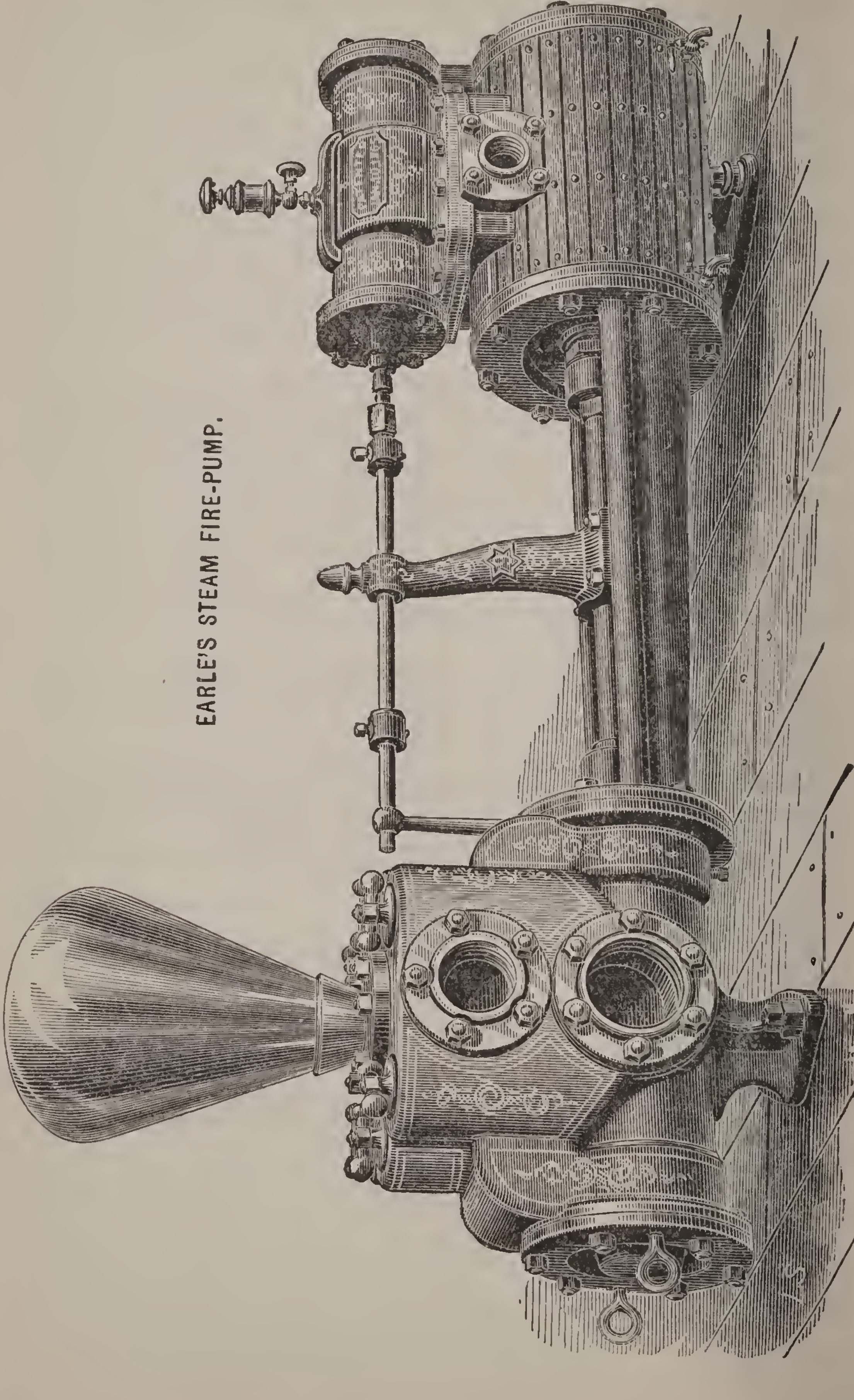
The steam pressure to be used.

From what height the water is to be lifted by suction.

The length of the suction-pipe.

Against what pressure or to what height the water is to be forced.

The greatest quantity of water that will ever be needed in a given time.



EARLE'S STEAM FIRE-PUMP.

EARLE'S STEAM FIRE-PUMP.

In the cut on the opposite page is shown Earle's Steam Fire-Pump, manufactured by the Norwalk Iron-Works Co., Norwalk, Conn. From its general appearance it will be seen that the arrangement of the parts is such as to insure ease of management, and that the interior parts — the valves, plungers, etc.,— are all easily accessible. The valve-seats are made of gun-metal, and, being fitted to gauges, and turned tapering and driven into the pump, can easily be removed either for renewal or repairs. The pumping-barrel is a composition tube, bearing at its ends upon collars turned in the main casting, which serve as guides to hold it central, and is held securely in its position by the piston-rod stuffing-box screwing into one end, and drawing the tube or bushing against a shoulder at the other end, thus making it perfectly tight, firm, and solid. This forms the pumping-cylinder.

When the bushing becomes excessively worn, it is the work of but a moment to unscrew the stuffing-box,—which, being of gun-metal, cannot rust in the thread,—take out the bushing, replace it immediately with another, and re-bore it at leisure. The introduction of a water-cylinder, which can be introduced with little delay, is a practical remedy in case of worn or cut cylinders. As the collars in the pump and on the bushing are all accurately fitted to gauges, no pipe connections need be disturbed, and no delay experienced in making the adjustment.

For Earle's Steam-pumps are claimed simplicity, durability, and efficiency; they are adapted to any or all the purposes for which steam-pumps are used, and are manufactured in sizes varying from 3½ inch steam-cylinder, 2 in. water-cylinder, up to 30 in. steam-cylinder, 20 in. water-cylinder.

DIRECTIONS FOR SETTING UP STEAM-PUMPS.

Never place a pump further than 25 feet from the water-level, as the nearer the pump-valve is to the surface of the water, the more rapidly the pump will discharge.

Pipes fully as large as the pump connections should be used in all cases, and, where it becomes necessary to use long or crooked pipes, they should be even larger.

The suction-pipe is the most important of all the pipes to a pump, since, if this does not perform its duty, and furnish water in sufficient quantity to fill the cylinder as fast as the water-piston travels, no matter how well the other pipes are arranged, the result will be unsatisfactory; hence the great necessity of keeping this pipe in good order.

The suction-pipe should always be as short and direct as possible, and, if the lift is high, it should have a check-valve at its lower end. It should also have a strainer on the end, of about twice the area of the pipe, and, where it becomes necessary to use a valve in this pipe, it should be one with a round water-way, like the "Peet" or "Ludlow," as ordinary globe-valves or stop-cocks diminish the supply of water.

It requires four times the force to deliver a given quantity of water through a pipe 200 feet long, that it would require to deliver the same quantity through a pipe one diameter of the same pipe in length; hence the necessity of using pipes of larger diameters when the supply is distant from the pump.

Leaks in the suction-pipes of pumps should be carefully guarded against, as a very small leak will destroy the efficiency of a good pump.

Short bends and angles in pump-pipes should be avoided as much as possible, as they retard the flow of the water;

but when they must necessarily be used, they should be as large as practicable.

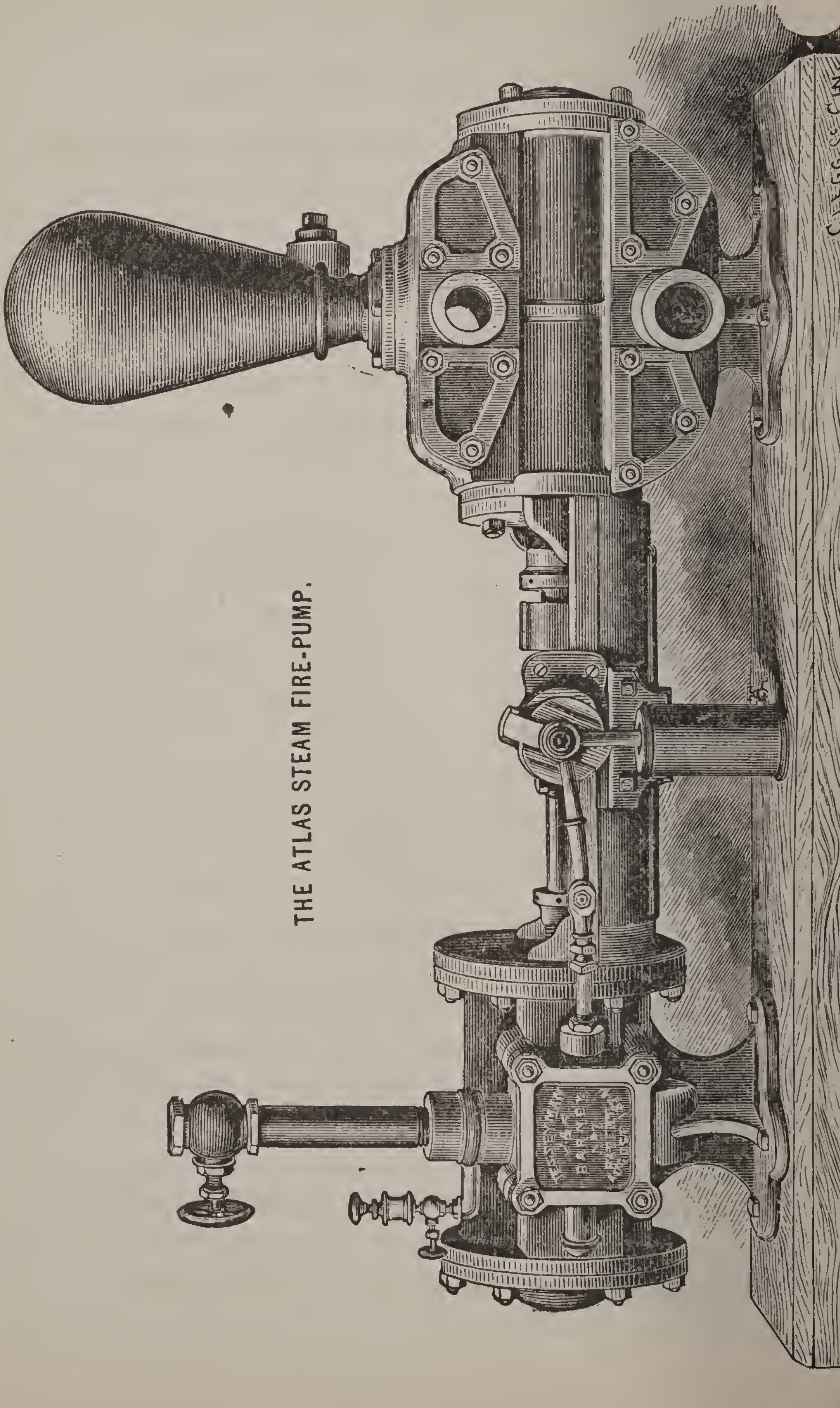
The same rules that govern the proportions of suction-pipes apply also to those of discharge-pipes. It is a very general impression among persons not acquainted with this subject, that if the discharge runs perpendicularly from the pump, it should be small, in order to diminish the weight of the column of water resting on it. This is a mistake, as the pressure on a pump-piston, from a vertical column of water one inch in area, would be about as much as if it was two; while a two-inch pipe would have four times the delivering capacity of the one-inch pipe, and therefore much less friction.

Discharge-pipes should be of a uniform diameter throughout, as any reduction in the diameter of a pipe greatly diminishes its capacity. A steam-pipe of the size which a pump calls for, is generally large enough for the fastest running pumps, but in cases where it is extremely long, a pipe one size larger might be advisable. It should also be protected by some good non-conductor or covering.

The exhaust-pipe should be the full size the pump calls for, and, where it is possible, should be run down, in order to allow the water of condensation to flow out.

When pumping hot water, pumps may be made to work smoothly by connecting a stand-pipe, open at one end, to the supply-pipe, near the pump, and running the open end up a little above the supply; the raising and lowering of the water in this pipe at each stroke, will relieve the pump, and also admit of an easy escape of the steam rising from the hot water.

The pipes of all pumps located in exposed situations, should be furnished with unions, in order that they may be separated from them in extremely cold weather.



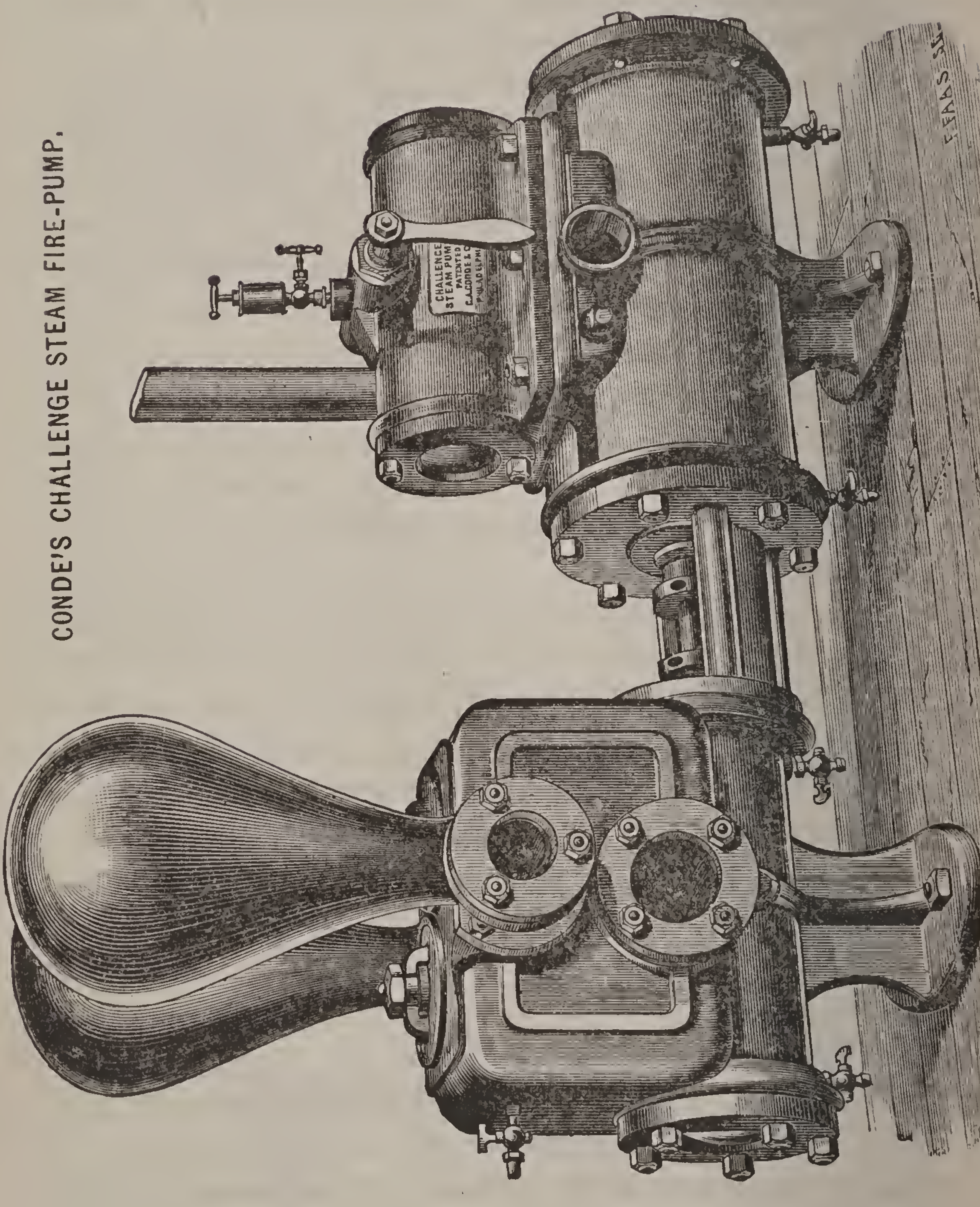
THE ATLAS STEAM FIRE-PUMP.

THE ATLAS STEAM FIRE-PUMP.

The cut on the opposite page represents the Atlas Steam Fire-pump, which is especially adapted for fire, marine, mining, tanning, and wrecking purposes; or, in fact, for any place where it is desirable to displace large quantities of water in a short time, such as filling tanks and reservoirs, draining mines or quarries, or freeing the holds of vessels from water in case of leakage, etc.

It is a double, direct-acting pump; in its construction the common slide-valve is used, and operated by a peculiar rocker and cam motion, which is so constructed that it is impossible for it to stop on the dead-centre, since, as soon as the motive power is admitted to the cylinder (whether steam, water or air pressure), the pump begins to operate, and it is impossible to place the valve in such a position as to shut off steam and stop the pump. By a peculiar arrangement for moving the steam-valve, a full stroke is insured, but at the same time, by means of a guide to the valve motion, the stroke is slowed down, thus giving the water-cylinder time to fill, insuring a full stream every time, and preventing the plunger or water-piston from cushioning against the water when the cylinder is but partly filled. The water-valves are made especially for the work which the pump is required to do, and are generally constructed of gun-metal, or of such other material as is least affected by the liquid passing through them. The openings are straight and clean, without small or intricate passages to be filled up with sediment or dirt.

Among the most valuable features of this pump are its great simplicity, durability, and effectiveness. They are manufactured by Smith, Vaile & Co., Dayton, Ohio.



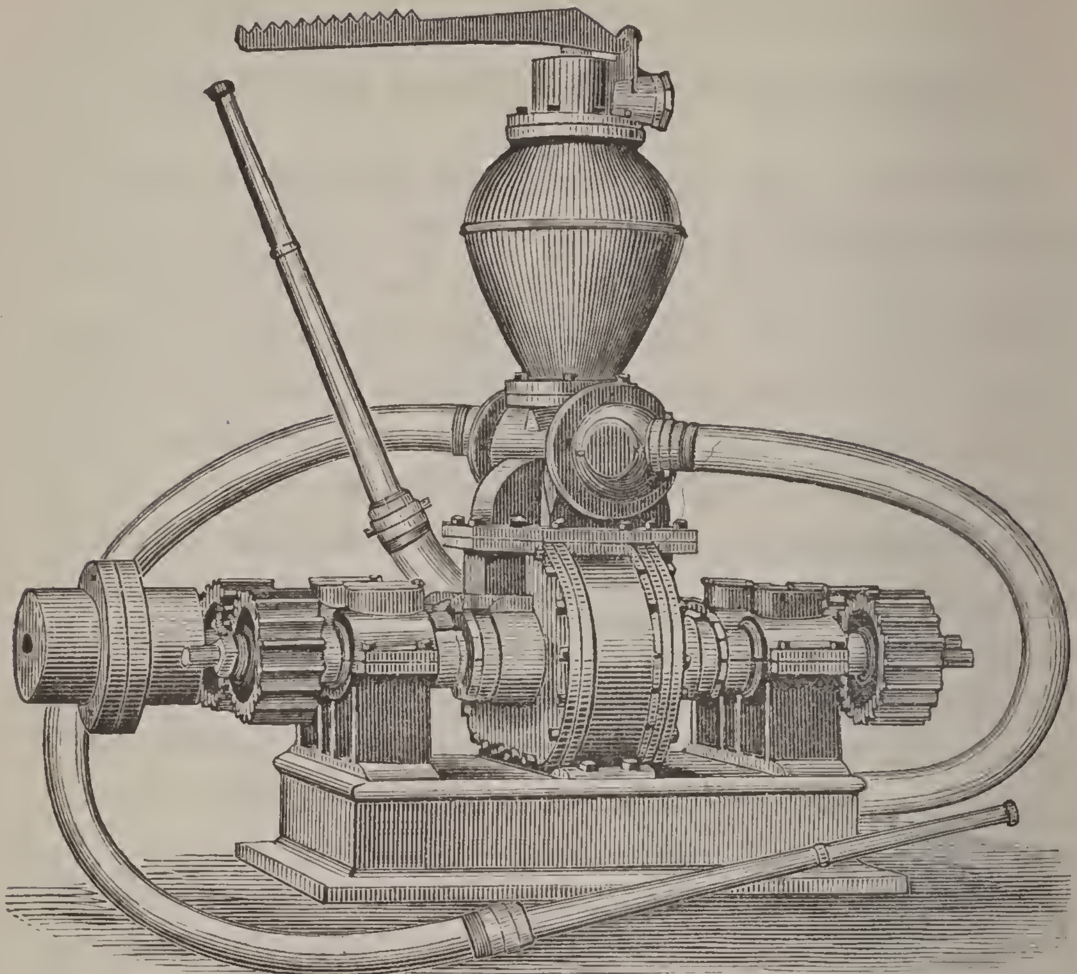
CONDE'S CHALLENGE STEAM FIRE-PUMP.

CONDE'S CHALLENGE STEAM FIRE-PUMP.

The cut on the opposite page represents Conde's Challenge Steam Fire-pump, manufactured by C. A. Conde and Co., Philadelphia, the peculiar advantages of which consist in doing away with all outside arrangements for operating the valves; that the steam-cylinder is brought into such close connection with the pump as to give it a very compact form, and that the working parts are so few and simple, as to render them not at all liable to any disarrangement. The steam-cylinder is made open at both ends, which admits of an easy adjustment; while the valve-chamber is fitted to it by a ground joint, and can be removed at any time without interfering with the steam-pipe connections, as they enter the cylinder casting below it.

The steam-valve consists of a slide-valve and a plunger, which throws the valve by the action of the exhaust steam. By this arrangement the cylinder is relieved from all pressure before the plunger reaches the end of its stroke, the pressure on the slide-valve checking it. The valve has a variable throw in proportion to the work to be done by the pump. The water-cylinder and valve-chamber are cast in one piece; the water-valves are of a very convenient form, and can be removed from their seats for cleaning, inspection, or renewal, without taking off any bonnet, and be replaced in a very few minutes.

The Challenge Pump is in very general use, and gives entire satisfaction. It is exceedingly well adapted to the purpose of extinguishing fires, as it will start at any point of the stroke when the steam is turned on, can be run at a very high speed, and is capable of displacing a large volume of water in a short space of time.



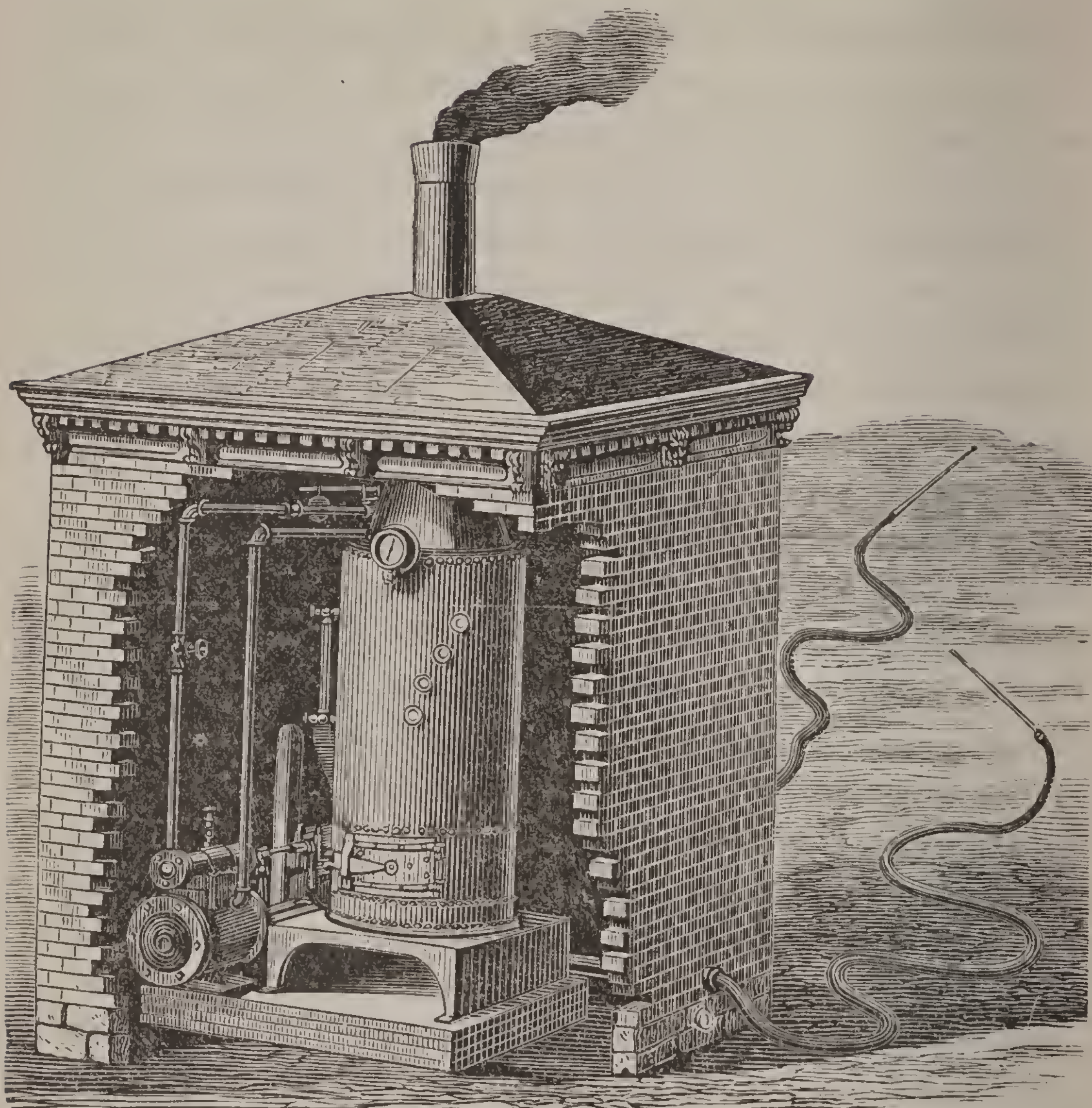
HOLLY'S ROTARY STEAM FIRE-PUMP.

The above cut represents Holly's Rotary Steam Fire-Pump, manufactured by the Silsby Manufacturing Co., Seneca Falls, N. Y. In the working parts of this pump, valves and packing are dispensed with. The cams on the piston are packed by the simple action of the water forced into grooves planed into their ends for that purpose. The water enters the case at the bottom through the suction-pipe; the stream then divides and fills the chambers made by the long cams on each side, and inside of the case, passing round and discharging at the top. It is claimed that by this arrangement the suction is more perfect than can be obtained in piston-pumps,

as the instant the pump starts, it begins to exhaust the air in the suction-pipes, and will continue to do so as long as any remains in the pipe, provided the suction is not so long that the air cannot be exhausted by any pump. It is also claimed that these pumps will not clog, as any substance taken in with the water will pass through and be discharged, without in any way interfering with the pump; moreover, as the cams do not rub against the inside of the case, there is very little friction to overcome, consequently the pump is capable of developing great power.

At an early period in the history of machines for raising water, it became a desideratum, with engineers, to obtain a continuous rotary movement of the piston-rod in place of the ordinary rectilinear and reciprocating one, in order that the walking-beam, crank, connecting-rod, or fly-wheel might be reduced or abandoned, and the power saved that was consumed in overcoming their inertia and friction at every stroke of the piston. Reasoning analogous to this had long before led some old mechanicians to convert the motion of the common pump-rod into a circular one; in other words, to invent rotary pumps. By this, the power expended in constantly bringing all the water in the cylinder and suction-pipe alternately to a state of rest and motion, was saved, as the liquid is kept in constant motion in passing through them.

The Holly Rotary Pumps are in very general use as fire-pumps, and have the reputation of being very efficient, as they can be run either slow or fast, and are capable of displacing a great quantity of water in a short time—the quantity being in proportion to the number of revolutions made by the pump. They are also very reliable, as they will always start when the steam is turned on. The mandrils are made of the best cast-steel, which renders them very strong, durable, and not liable to wear.



PROPER METHOD OF LOCATING STEAM FIRE-PUMPS.*

The above cut illustrates the proper method of locating steam fire-pumps for the protection of factories, hotels, railroad depots, warehouses, or, in fact, any kind of property exposed to the ravages of fire. Such a building as shown in the cut may be constructed of brick, with corrugated iron roof, and iron doors on different sides, at a very trifling expense. With an efficient steam-pump

* See page 36.

located in such a building, and one or two lines of hose, almost any fire might be held in check by the employees of a hotel or factory, until some more powerful and efficient means might be brought into play. But independent fire-pumps, to be capable of rendering efficient service in emergencies, should be kept continually under steam, and be frequently tried, for the purpose of ascertaining if everything is in good working order. A good independent steam fire-pump, when judiciously located, thoroughly cared for, and well managed, can always be relied upon as a means of averting the devastating effects of fire, and consequently tend to lessen the rates of insurance on property.

THE INJECTOR.

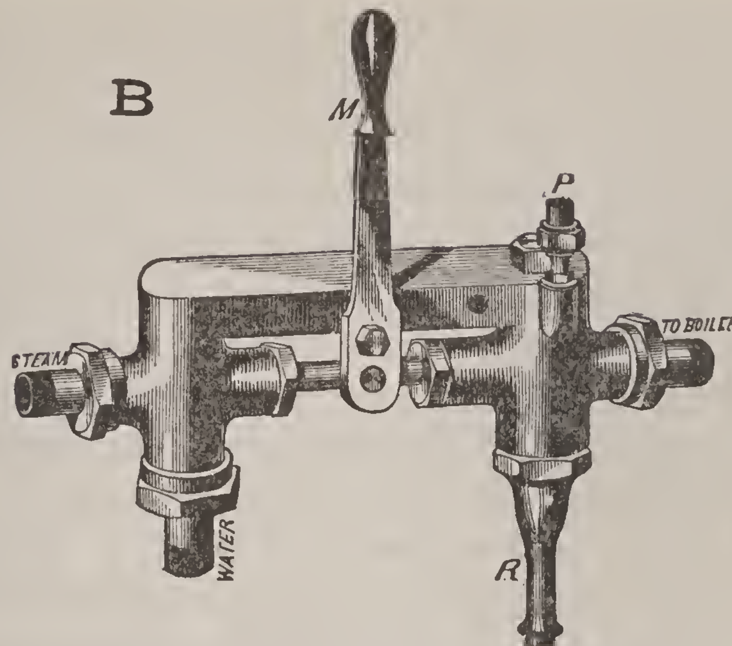
Of all the inventions of the mechanic and the scientist, none seemed to the uneducated to approximate so nearly to perpetual motion as the instrument now in general use as a boiler-feeder on locomotives and stationary engines, and known as the injector, and which, from common use, no longer excites the wonder even of those who do not understand its mode of operation.

It consists of a slender tube, called the steam-tube, through which steam from the boiler passes to another or inner tube, called the receiving-tube. The latter tube conducts a current of water from a pipe into the body of the injector. Opposite the mouth of this second tube, and detached from it, is a third fixed tube, called the delivery-tube. This tube is open at the end facing the water-supply, and leads from the injector to the boiler. The action of the injector is that which Venturi, in the beginning of the present century, designated as the "lateral action of fluids," and, having been investigated by Dr. Young,

in 1805, was proposed by Nicholson, in 1806, for forcing water. The action is identical with that of the steam-jet, or blower-pipe, in the chimney of the locomotive. The principle is, that steam, being admitted to the inner tube of the injector, enters the mouth of a combining tube, in the form of a jet, near the top of the inlet water-pipe. If the level of the water be below the injector, the escaping jet of steam, by its superficial action (or friction) upon the air around it, forms a partial vacuum in the combining tube and inlet-pipe, and the water then rises in virtue of the external pressure of the atmosphere. Once risen to the jet, the water is acted upon by the steam in the same manner as the air had been acted upon in first forming the partial vacuum into which the water rose.

Giffard's discovery was that the motion imparted by a jet of steam to a surrounding column of water was sufficient to force it into the boiler from which the steam was taken, and, indeed, into a boiler working at even a higher pressure. But the most important improvement ever heretofore made in the injector was made in 1868, by Samuel Rue, by which the injector, with steam of from 80 to 90 pounds pressure, is capable of forcing water against a pressure of from 400 to 450 pounds per square inch.

This extraordinary accumulation of power may be explained as follows: The velocity with which steam — say at 60 pounds pressure to the square inch — flows into the atmosphere is about 1700 feet per second. Now suppose that steam is issuing, with the full velocity due to the pressure in the boiler, through a pipe one inch in area, the steam is condensed into water, at the nozzle of the injector, without suffering any change in its velocity. From this cause its bulk will be reduced, say 1000, and, therefore, its area of cross-section — the velocity being constant — will experience a similar reduction. It will then be able



Rue's "Little Giant" Injector Letter "B."

to enter the boiler again by an orifice $\frac{1}{1000}$th part of that by which it escaped. Now it will be seen that the total force expended by the steam through the pipe, on the area of an inch, in expelling the steam-jet, was concentrated upon the area $\frac{1}{1000}$th of an inch, and, therefore, was greatly superior to the opposing pressure exerted upon the diminished area. As the Rue Injector is now successfully employed as a boiler-feeder on the Pennsylvania Line of Steamships, and as it is the only injector that can be used on ocean steamers, river boats, tug-boats, ferries, and pleasure-yachts, a description of the method of its adjustment and working will be of interest to engineers.

How to put on Letter "B" Injector.—Put the injector in a horizontal position above the foot-board, and within easy reach of the engineer, using as short a length of pipe for "steam" and "deliverance to the boiler" as possible. Put an ordinary globe or angle-valve on the steam supply-pipe for starting, etc., taking the steam from the highest part of the boiler, and attaching it to the swivel marked "steam." Attach the water supply-pipe to the

swivel marked "water," putting an ordinary water-cock on the supply-pipe near the injector. A good supply of water must be had, and, if taken from a tank, given a good fall. The mouth of the pipe should be enlarged, and a screen with small meshes placed over it to keep out dirt; if the supply-pipe be over ten feet in length, or if the water come from a hydrant, or any source that makes a pressure, and the supply is not at a regular pressure, the pipe should be one size larger than the swivel marked "water," which can be done by putting on a reducer. At this point turn on your steam and water, and let them flow through the injector, to see if the pipes and injectors are free from dirt. Then attach the "delivery-pipe" to the swivel marked "to boiler."

Method of Working Letter "B" Injector.—Turn on the water, and, when it flows from the overflow, turn on the steam, slowly at first, until it catches the water; then turn on full head, and push the lever M slowly either forwards or backwards, as seems requisite, until neither steam nor water shows at the overflow. Failure to work will always show at the overflow, and when the point is ascertained at which the lever is to be set for the steam pressure to be carried, it can be regulated, and then left to stand at that position when the steam and water are shut off. The lever is only used to regulate the proportionate amounts of water and steam. But when water is to be lifted by this injector, as on steamships, a small steam-pipe leading from the boiler, and furnished with a valve that opens with a quick motion, is attached to the swivel "P," by means of which a steam-jet is thrown into the tube "R," and the water lifted. But at this point it is necessary to examine the tube in order to ascertain if the suction is good, or if the water rises readily, and if so, the steam supply-pipe can be attached to the swivel marked

"steam," and the injector cleared of any dirt that may have collected in the boiler-pipes; then the delivery-pipe to the boiler may be attached to the swivel marked "to boiler." Great care should be taken to see that the supply-pipe, through which the water is lifted, is perfectly air-tight, as any leak in the pipe will interfere with the working of the injector.

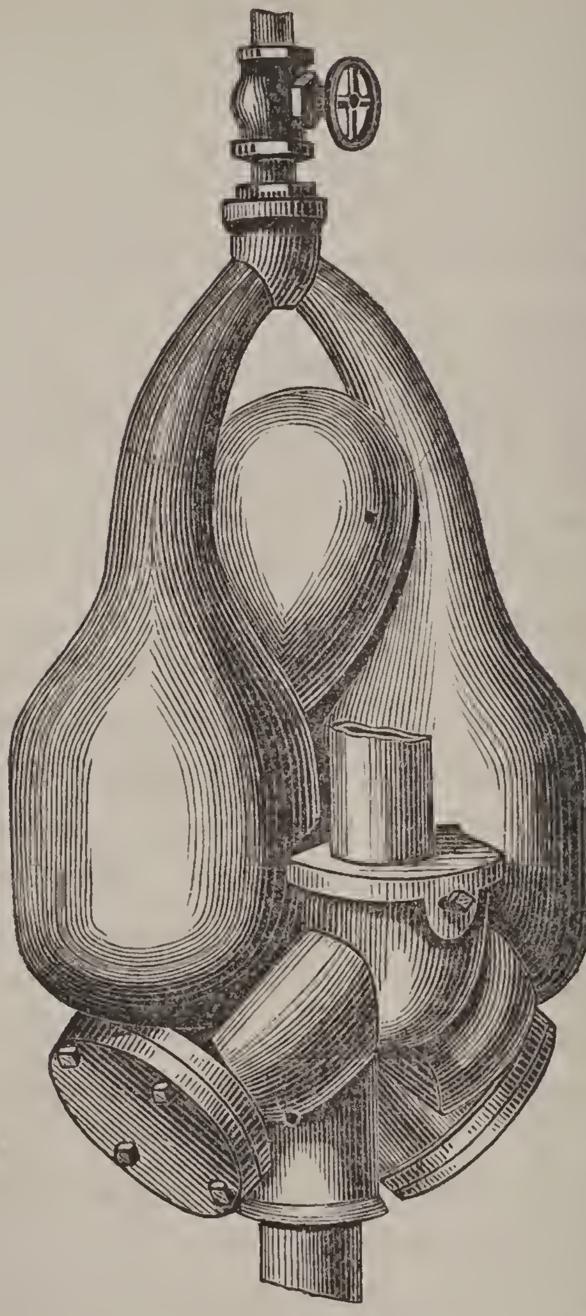
In ordering injectors, it should always be stated whether the connecting-pipes are copper, brass, or iron, and whether for steamships or stationary boilers.

TABLE

OF CAPACITIES OF RUE'S "LITTLE GIANT" INJECTOR.

Size of Injectors.	Size of Pipe Connections.	Pressure of Steam in Pounds.	Gallons per Hour.	Nominal Horse-Power.
0	$\frac{1}{4}$	90	60	4 to 8
1	$\frac{3}{8}$	90	90	6 " 12
2	$\frac{1}{2}$	90	120	8 " 20
3	$\frac{3}{4}$	90	300	20 " 40
4		90	600	40 " 80
5	$1\frac{1}{4}$	90	900	60 " 120
6	$1\frac{1}{4}$	90	1200	80 " 160
7	$1\frac{1}{2}$	90	1620	140 " 225
8	2	90	2040	200 " 275
9	2	90	2480	250 " 350
10	2	90	3000	300 " 400
12	$2\frac{1}{2}$	90	3600	350 " 500

The Injector is very desirable as a boiler-feeder for steam fire-engines; but the great obstacle in the way of its successful employment is, that nearly all that class of machines work wet steam, which, of course, is the result of a small steam space, and the rapid flow of the steam from the boiler to the cylinder.



THE PULSOMETER.

The cut on this page represents the Pulsometer. The conditions upon which the proper action of the pulsometer depends are similar, in all essential particulars, to those which pertain to the management of the ordinary double-acting piston-pump. But, although the pulsometer may be

operated under the same conditions as control the operation of piston-pumps, the arrangements should be made with judgment and discretion, to meet the characteristic difference existing between the two systems, and with special reference to the nature of the fluid to be pumped.

The pulsometer requires a free current of the fluid in an uninterrupted stream, as a necessary condition of its action. If the source of supply of the liquid be exhausted, or the induction passage is contracted so as to prevent its free admission in response to the vacuum impulses alternately created in the chambers above, the steam will blow through the discharge-pipe, and the pulsation will cease.

The pulsometer is peculiarly adapted for pumping water from mines, foundations, or excavations where quicksand or mud occur, as it will pump water combined with fifty per cent. of mud or sand without any derangement of its parts, as there is no cylinder, piston, or valves to cut or wear. It can also be used to irrigate land and drain swamps and ponds. It is also available as a bilge-pump on board ship, as it is not liable to become choked with grain or other substances. The pulsometer will raise water or any other liquid from a depth due to the vacuum produced by the condensation of steam, and will force the same to an elevation due to the initial pressure of the steam in the boiler operating it.

The pulsometer possesses some advantages in point of convenience, as it can be lowered into deep wells or mining-shafts, and, in fact, set or hung up in any place most convenient to the work or the steam; but it is less reliable in its action than the pump, and is very wasteful of steam.

THE HYDRAULIC RAM.

One of the most common methods of raising water by power is the so-called hydraulic ram; its effectiveness and

economy, together with the fact that it is applicable in thousands of situations now without any means of raising water, render a better knowledge of its operation extremely desirable. The hydraulic ram is decidedly the most important and valuable apparatus yet developed in hydraulics, for forcing a portion of a running stream of water to any elevation proportionate to the fall obtained.

It is perfectly applicable where no more than 18 inches fall can be had; yet the greater the fall applied, the more powerful the operation of the machine, and the higher the water may be conveyed. The relative proportions between the water raised and wasted are dependent entirely upon the relative height of the source of supply above the ram, and the elevation to which it is required to be raised — the quantity raised varying in proportion to the height to which it is conveyed, with a given fall. The distance which the water has to be conveyed, and consequent length of pipe, has some bearing on the quantity of water raised and discharged by the ram; as the longer the pipe through which the water has to be forced by the machine, the greater the friction to be overcome, and the greater the power consumed in the operation.

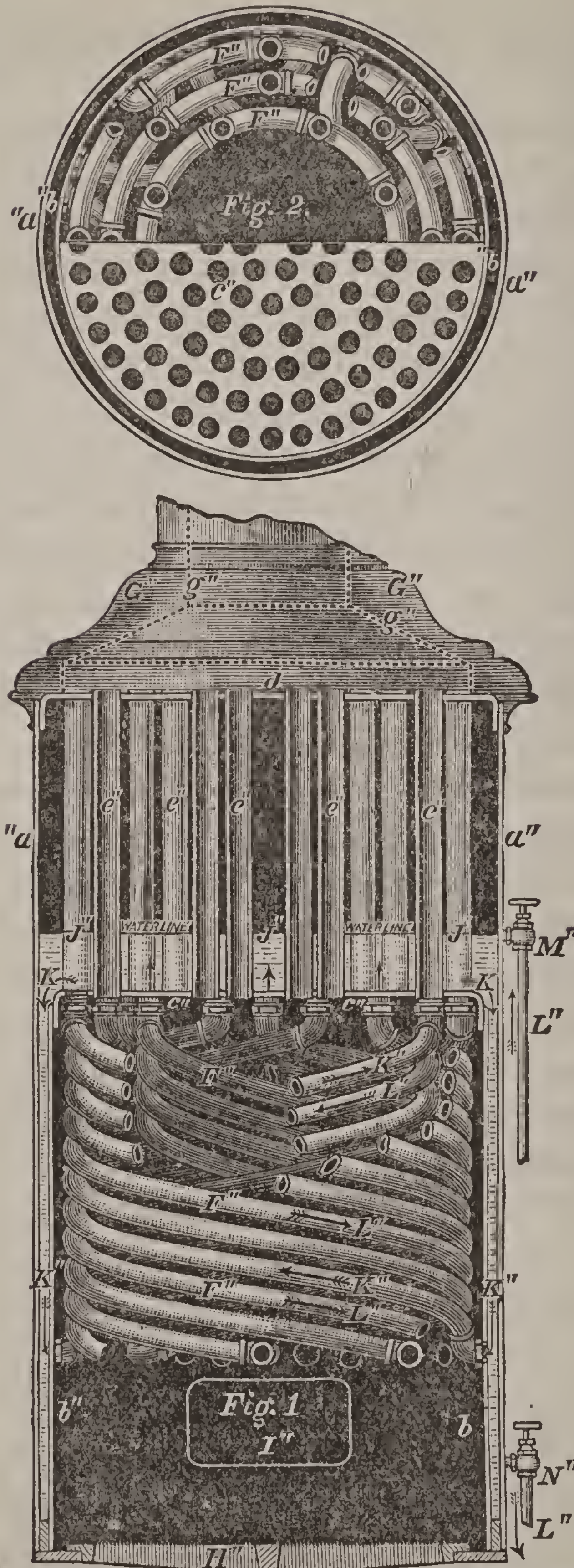
Yet it is a common thing to apply the ram for conveying water distances of from one to two hundred rods, and up elevations of from one to two hundred feet. Ten feet fall from the spring or brook to the ram is abundantly sufficient for forcing water up to any elevation under, say, one hundred and fifty feet in height above the level of the point where the ram is located; and the same ten feet fall will raise water to a much higher point than that, although in a diminished quantity, in proportion as the height is increased.

When a sufficient quantity of water is raised with a

given fall, it is not advisable to increase said fall, as, in so doing, the force with which the ram works is increased, and the amount of labor which it has to perform greatly augmented; the wear and tear of the machine are proportionately increased and its durability lessened, so that economy, in the expense of keeping the ram in repair, would dictate that no greater fall should be applied for propelling it than is sufficient to raise a requisite supply of water.

To enable any person to estimate what fall would be sufficient to apply to the ram to raise a sufficient supply of water, it may be safely calculated that about one-seventh part of the water can be raised and discharged at such an elevation above the ram as is five times the height of the fall which is applied to the ram; or one-fourteenth part can be raised and discharged ten times as high as the fall applied; and so on in the same proportion according as the fall or the rise is varied.

Thus, if the ram be placed under a head or fall of five feet, for every 7 gallons drawn one may be raised 25 feet, or half a gallon 50 feet. Or with 10 feet fall applied to the machine, of every 14 gallons drawn from the spring, 1 gallon may be raised to the height of 100 feet above the machine; and so on in like proportions, as the fall or rise is increased or diminished.



CLAPP & JONES' VERTICAL CIRCULATING TUBULAR BOILER.

Description on Page 57.

BOILERS OF STEAM FIRE-ENGINES.

The vertical tubular boiler is the form most generally used for fire-engines; not that it possesses any advantages in raising or keeping up steam, or in economy of fuel, but simply because it occupies less space, admits, when properly designed, of a great power being obtained, with great strength, in a very small space, and is better adapted for that particular purpose than any other type of boiler now in use. In the design of such boilers, it is necessary to provide a very large amount of heating surface, which, of course, must limit the water space; consequently, as they are intended to raise steam very rapidly, as well as sustain high pressures, they should be scientifically designed, carefully constructed, and none but the best description of materials employed in their construction.

The boilers of steam fire-engines should be so designed, as to insure the most complete and perfect circulation of the water, so that the steam formed by the contact of the water with the heated surfaces may escape into the steam-room of the boiler, and allow its place to be taken by a fresh supply of water, as a defective circulation of the water causes an imperfect generation of steam, which induces an over-heating of different parts of the boiler, and hastens its destruction. Rapidity of evaporation depends upon rapidity of circulation; as heat is conducted with great rapidity through metals, provided that the inner surfaces are kept constantly in contact with the water to be evaporated, and not with a non-conductor composed of over-heated water or steam.

Experience has shown that where it becomes necessary to contract the water space in a boiler, for the purpose of raising steam quickly, such arrangements have a tendency to induce other evils, as it causes an irregularity of action

in the boilers, such as unsteadiness of maintaining steam at the necessary pressure, and water at the ordinary level, which necessitates greater care and skill on the part of the attendants than need be devoted to boilers of more liberal and uniform proportions. It is very important in subdividing, as far as possible, the heat generated by the fuel, by the heating surface for evaporating the water, that this should be done without impeding the easy circulation of the water over this heating surface, otherwise, the durability and efficiency of the boiler are easily and quickly destroyed.

In order to obtain this with the greatest certainty and rapidity, it is of the first importance to secure the rapid and constant replacement, in contact with the highly heated surfaces, of an equal body of water at a lower temperature, to take the place of that which has passed off in a state of steam at a high temperature. This, it will be seen, can only be obtained in a ready and simple manner, by securing the most complete circulation of the water in the boiler, over and in contact with all the heated surfaces. The boilers of steam fire-engines are designed on different plans; but the great and paramount object which seems to be sought for in all, is a rapid and steady production of steam, with a maximum of strength and a minimum of weight.

The boilers of fire-engines, like those of locomotives, are subjected to many severe shocks and strains,—chief among which are the pressure of the steam, the jarring of the machine when driven over unequal surfaces, the unequal expansion and contraction of the plates, induced by excessive heat, defective design, or the pumping in of cold water when the iron is expanded to its utmost limits; all these strains combined affect the several parts of the boiler, the intense heat rendering the part on which it acts crystalline, or liable to fracture. The jar and strains have

a tendency to loosen the rivets, and weaken the whole structure. Consequently, the boiler of a fire-engine must evidently possess other features of strength than those required in an ordinary steam generator, as there are unavoidable connections and attachments to be made here and there, which can only be maintained under superior stability of parts; however strong and independent the framework of a fire-engine may be, the simple holding of it in its place by the boiler necessitates considerable extra stiffness.

Regarding the boiler of a steam fire-engine as a cylinder with flat ends, the strain is necessarily greatest on the longitudinal seams, and less on the curvilinear; therefore the former should, in all cases, be double riveted; while the latter, having to bear only one half the strain, is proportionately stronger in respect to strains arising from steam pressure with single rivets, than the longitudinal is with double rivets.

It is extremely desirable that boilers which evaporate water with great rapidity and contain but a small quantity, such as the boilers of steam fire-engines, should be provided with different means of replenishing it, so that in case of accident to any one of them, the other might be available, thus preventing the necessity of drawing fire, and thereby diminishing the risk of burning or injuring the boiler. Reliability, simplicity, efficiency, freedom from derangement, and great facility in remedying defects, are most important points to be secured in the feed apparatus attached to the boilers of steam fire-engines.

All boilers of small size, where a large amount of water is evaporated at a high temperature in a short space of time, naturally require frequent blowing off, in order to get rid of the solid matter and deposit contained in the water, which remains in the boiler when the water is

evaporated. It is highly important that this should be carefully attended to, especially if the boiler is kept continuously at work. If this is properly done, all the deposit and residuary matter which would harden in the interior, will be got rid of, and prevented from forming an incrustation or scale in the boiler, thus obviating the trouble and expense of removing the tubes for the purpose of cleaning the crown- or tube-sheet directly over the fire, which very often has to be done in consequence of the accumulation of deposit on its upper side. But no boiler should ever be blown out under steam pressure, or while hot, as the heat of the iron, after the water is all out, soon dries and hardens the scale on its surface, thereby forming a coating which is impervious to water, thus rendering the parts of the boiler exposed to the action of the fire liable to become crystallized and burned.

Boilers should be allowed to stand for several hours after being used, before the water is run out; by this course the deposit on the parts of the boiler most exposed to the action of the fire, may be kept soft and porous for years, which obviates the danger of burning the boiler; nor should they ever be filled with cold water while hot, as this has a very injurious effect on the different parts, causing severe contraction of the seams, braces, and tubes, which frequently results in fracture and leakage, and eventually in the destruction of the boiler. Many boilers well designed, well constructed, and of good material, have been ruined while yet new through ignorance and injudicious management.

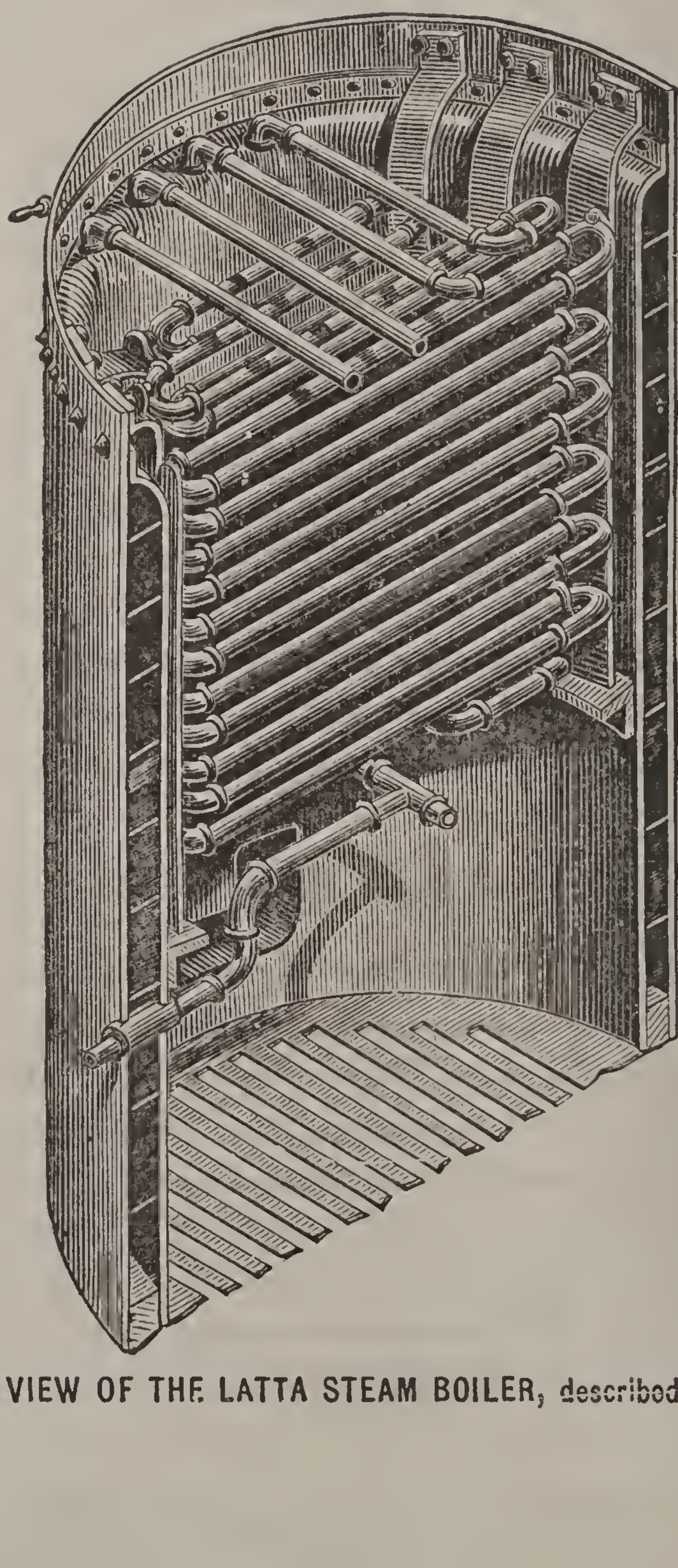
In all boilers with small and contracted water spaces, like those of fire-engines, some solvent should be used for the purpose of keeping the scale or deposit in a plastic state, until such time as it can be removed; but the character of the solvent should be thoroughly understood, as,

if it contains acid of any kind, it is liable to do more harm than good. Lord's Boiler Compound has been used for several years in thousands of boilers of every description, and under very varying circumstances, and in all cases with the most satisfactory results. It removes old scale, prevents the formation of new, and chemical analysis has shown that it contains no acid whatever.

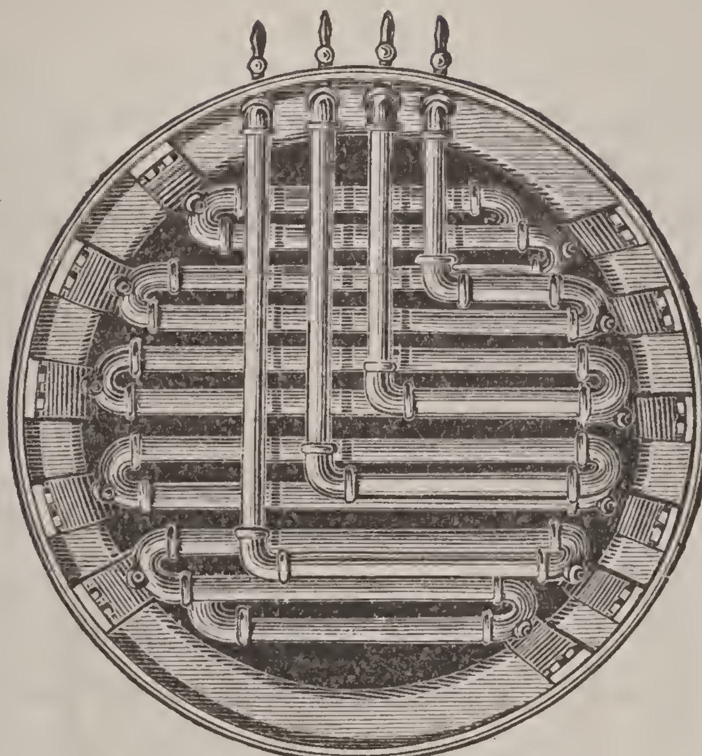
Any boiler, if left too long without cleaning, especially if muddy water be used, is liable to foam, which is invariably attended by serious results, detrimental both to the steam-cylinder and the boiler, as, during the process of foaming, the water is lifted from the surface of the plates, rendering the iron liable to become overheated, which frequently results in the bulging or cracking of the parts most exposed to the direct action of the fire. The mud and grit which are disturbed by the agitation of the water induced by the foaming, pass into the cylinder, and flutes both the cylinder, the rings, and rod, which causes them to leak, involving the necessity of expensive repairs.

CAUSES OF FOAMING IN STEAM-BOILERS.

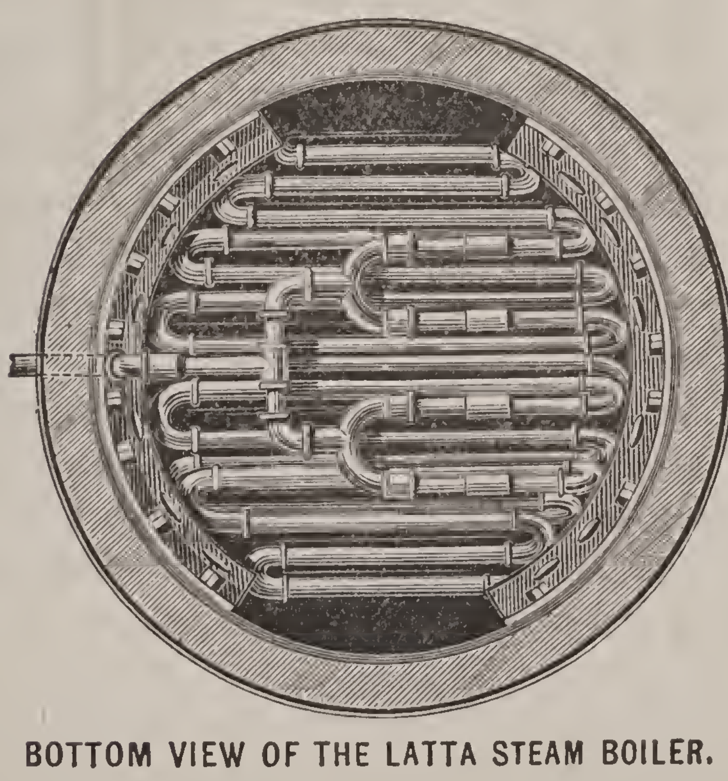
A boiler foams or primes, either because it has insufficient steam room, or on account of dirt or grease in the boiler or the feed-water. The trouble is often experienced with new boilers, and disappears when they become clean. Priming is dangerous, if much water is carried over with the steam, as it is difficult to maintain a constant water level, and the engine is liable to be broken by the water in the cylinders. If the trouble is caused by insufficient steam room, it may sometimes be partially overcome by increasing the steam pressure, and throttling it down to the ordinary working pressure in the cylinder; but the only effectual mode is to provide more steam room. If



SECTIONAL VIEW OF THE LATTA STEAM BOILER, described on page 47



TOP VIEW OF THE LATTA STEAM BOILER.



BOTTOM VIEW OF THE LATTA STEAM BOILER.

the priming is due to dirt or grease in the boiler, the engineer should blow off frequently, and clean the boiler every few days. In blowing off, it is well to raise the water level in the boiler, by putting on a strong feed, and then blow down below the level that is ordinarily maintained. It is very often the case that the water level is higher when the engine is running, than it is when none of the steam is being used. The engineer should ascertain how much higher the water rises in such a case, so as to have a proper quantity of water when the engine is stopped.

Boilers of steam fire-engines, as well as all others, should be carefully examined and proved by hydraulic test, at least once a year; but such tests and examinations should be conducted by skilled mechanics and experienced boiler inspectors only, for ignorance of the real requirements of the examination or test may result in serious injury, as the hydrostatic test may prove either a guarantee of safety, or means of destruction, according to the intelligence or ignorance of the party by whom it is applied. The great number of defects in steam-boilers that must eventually lead to accident, brought to light every year by the trained inspectors of the "Hartford Steam Boiler Inspection and Insurance Company," and the immunity from boiler explosions, which every steam using community having their boilers in charge of that company, has enjoyed for the past seven years, goes to show the importance of steam boiler inspections, when conducted by competent parties. In fact, steam-boilers in general are not cleaned, tested, or inspected half as often as they should be.

EVAPORATION IN STEAM-BOILERS.

As the particles of water rise heated from the bottom of the boiler, other particles necessarily subside into their places; and it is a point of considerable importance to ascertain the direction in which the currents approach the plate to receive heat. A particle of water cannot leave the heated plate until there is another particle at hand to occupy its position; therefore, unless a due succession in the particles is provided for, the plate cannot get rid of its heat, and the proper formation of steam is prevented. It may be stated, as a general theory, that vaporization does not depend on the quantity of heat applied to the plate, but on the quantity of heat abstracted from it by the particles of water as they successively take their places upon that part to which the fire is applied. It will follow, as a necessary deduction from this fact, that the amount of vaporization of steam generated will depend upon the quickness with which cold atoms of water gain access to the heated portions of the vessels, while the hotter atoms are driven off. An engineer, therefore, will give a careful consideration to the means of promoting that access of the water to one side of the plate and of heat to the other.

Experiments and facts tend to show that every facility should be provided for enabling steam to make its exit from the bottom of the boiler; that ample space should be given at the ends or sides of the boiler for the circulation of the large body of water which, having parted with its steam, is now again returning to the heated plates at the bottom. It is highly desirable that the water should be made to circulate around the sides of the boiler; because, as water almost invariably contains portions of lime and other earthy salts, this sediment will be deposited on those portions of the boiler where they can do little

harm, and away from the tubes, which would be much injured by incrustations. This observation, of course, applies only to those boilers where the fire is located in the middle, or in which it passes through tubes, and where no excessive heat is likely to touch the parts incrusted. It has been proved beyond doubt that no boiler can be injured by heat as long as its plates are in contact with water; these points have been settled by a great variety of experiments.

INTERNAL AND EXTERNAL CORROSION OF STEAM-BOILERS.

Internal and external corrosion are two of the maladies that affect the integrity and limit the usefulness of steam-boilers.

Internal corrosion presents itself in various forms, each having a peculiar character of its own, though only sometimes strongly marked; these are designated as *uniform corrosion*, *wasting*, *pitting*, *honey-combing*, and *grooving*.

External corrosion is said to be due to galvanic action, or the influence of chemicals and dampness combined. Uniform corrosion is that description of wasting of the plates or tubes, where the water corrodes them, in a more or less uniform manner, in patches of considerable extent, and where there is usually no well-defined line between the corroded part and the sound plate.

The presence of this as well as of other kinds of corrosion can generally be easily detected, even when covered with a considerable thickness of incrustation, as its presence is often revealed on emptying the boiler by the bleeding, or red streaks, where the scale is cracked; although in some cases, even where the plates are free from incrustation, uniform corrosion, in consequence of its even surface and

the absence of any well-defined limit to its extent, may sometimes escape detection.

Even when actually discovered, the depth to which it has penetrated can only be ascertained by drilling holes through the plate and measuring the amount of material remaining. With lap-joints, the thickness remaining at the edge of the plate and round the rivet-heads may serve as a guide to the amount of wasting; but this may prove treacherous, since the adjacent plates may both be corroded to an equal extent along with the rivet-heads, which will give the edge of the plate the appearance of having the original thickness.

Another peculiarity worthy of notice is the different manner in which the plates and rivet-heads are affected by different kinds of waters after the wasting has been going on for some time. In most cases the corroded iron is readily removed, if it does not come off without means being taken to detach it. But cases are to be met with where the corroded iron adheres tenaciously to the sound plate beneath. In such cases considerable force is required to remove it, and the presence of the corrosion is not suspected until the hammer or pick is forcibly applied.

It frequently occurs that in the case of two boilers alike in every respect, fed with the same water and subject to the same treatment, one may be found attacked at the front end, whilst the other may be affected only on the bottom at the back end.

With the feed-water from one supply only, corrosion is found more often under an incrustation of sulphate of lime than under one consisting chiefly of carbonate of lime. In many boilers fed with water containing the former salt, a coating of oxide of iron of a black color may be found adhering to the detached scale, which, as often as it reforms and is broken off, brings with it a fresh film of oxide.

Various means, such as the use of rain, surface, and distilled waters, have been employed for the prevention of internal corrosion; but they were all found impracticable and generally abandoned, as the expense involved in most cases was found to exceed that of replacing the corroded boiler with a new one, even after a service of only a few years. Lord's Boiler Compound appears to be the only known remedy that affords any protection to boilers against the fearful effects of this singular and mysterious phenomenon, as it has been found to neutralize the mineral ingredients of the most destructive waters, and prevent the internal corrosion and wasting of boiler-plates, seams, and rivets.

External corrosion is frequently more destructive than internal, particularly in the case of stationary boilers. This probably arises from the fact that its presence is less suspected, and is often less easily detected in consequence of the covering of brickwork or other material surrounding the shell. The most frequent causes of external corrosion are exposure to the weather, leakage from seams, dripping from safety- or other valves, moisture arising from the ground, either from the damp nature of the location or from the want of proper appliances to carry off the waste water.

A slight leakage from a bad joint may be sufficient to cause a severe local grooving at the seam or flange, as it often goes on for a length of time unperceived and unsuspected, especially when the shell is covered by brickwork, or other material to prevent the radiation of heat, as in such cases, if a leak takes place on the upper side of the boiler, the whole circumference of the shell is liable to suffer from it. One of the most remarkable phenomena connected with all kinds of corrosion is the singular manner in which they make their appearance and act,

affecting very few boilers alike, or even in the same locality.

Corrosion of Marine Boilers. — Marine boilers seldom last more than four or five years; whereas land boilers, made of the same quality of iron, often last fifteen or twenty years; yet the difference in durability is not the effect of any chemical action upon the iron by the contact of sea-water, for the flues of marine boilers rarely show any deterioration from this cause; and even in worn-out marine boilers, the hammer-marks on the flues are as conspicuous as at the time of their formation.

The thin film or scale spread over the internal parts of marine boilers would seem of itself to preserve that part of the iron from corrosion which is situated below the water-level; but, strange as it may seem, it is rare to find any internal corrosion of boilers using salt-water, in those parts of the boiler with which the water comes in contact; the cause, therefore, of the rapid corroding of marine boilers is not traceable to the chemical action of salt-water, as steamships provided with surface condensers, which supply the boilers with fresh-water, have not reaped much benefit in the durability of their boilers.

Corrosion of steam-boilers is one of the most obscure subjects in the whole range of engineering.

RULES.

Rule *for finding the Safe Working Pressure of Iron Boilers.*—Multiply the thickness of the iron by .56 if single riveted, and .70 if double riveted; multiply this product by 10,000 (safe load); then divide this last product by the external radius (less thickness of iron): the quotient will be the safe working pressure in pounds per square inch.

EXAMPLE.

Diameter of boiler..............................42 inches.
Thickness of iron................................ $\frac{3}{8}$ inch.

2)42
———
21 external radius.
.375
———
20.625 internal radius.

Thickness of iron $\frac{3}{8}$ = .375
.56 single riveted.
———
2250
1875
———
.21000
10000 safe load.
———
20.625)2100.00000
———
101.81 lbs. safe working press.

In the above rule, 50,000 pounds per square inch are taken as the tensile strength of boiler iron, and one-fifth of that, or 10,000, as the safe load. Hence five times the safe working pressure, or 50,000 pounds, would be the bursting pressure.

Rule *for finding the Safe Working Pressure of Steel Boilers.*—Multiply the thickness of steel by .56 if single riveted, and .70 if double riveted; multiply this product by 16,000 (safe load); then divide this last product by the external radius (less thickness of steel): the quotient will be the safe working pressure in pounds per square inch.

EXAMPLE.

Diameter of boiler..............................44 inches.
Thickness of steel................................ $\frac{1}{4}$ inch.

2)44
———
22 external radius.
.25
———
21.75 internal radius.

$$
\begin{array}{rl}
\text{Thickness of steel } \frac{1}{4} = .25 & \\
.70 & \text{double riveted.} \\
\hline
1750 & \\
16000 & \\
\hline
1050000 & \\
175 & \\
\hline
21.75)2800.000 & \\
\hline
128.73 & \text{safe working pressure.}
\end{array}
$$

80,000 being taken, in the above rule, as the tensile strength of steel, and one-fifth of that, or 16,000, as the safe load. Hence, 80,000 would be the bursting pressure.

Rule *for finding the Aggregate Strain caused by the Pressure of Steam on the Shells of Steam-boilers.*— Multiply the circumference in inches by the length in inches; multiply this product by the pressure in pounds per square inch. The result will be the aggregate pressure on the shell of the boiler.

EXAMPLE.

Diameter of boiler..42 inches.
Circumference of boiler..............................131.9472 "
Length " ....10 ft., or 120 "
Pressure " ....125 pounds.
131.9472 × 120 × 125 = 1,979,208 pounds ÷ 2000 = 989 tons.

RULE FOR FINDING THE HEATING SURFACE OF STEAM-BOILERS.

Rule for Locomotive or Fire-box Boilers.—Multiply the length of the furnace-plates in inches by their height above the grate in inches; multiply the width of the ends in inches by their height in inches; also, the length of the crown-sheet in inches by its width in inches; multiply the combined circumference of all the tubes in inches by

their length in inches; from the sum of the four products subtract the combined area of all the tubes and the fire-door; divide the remainder by 144, and the quotient will be the number of square feet of heating surface.

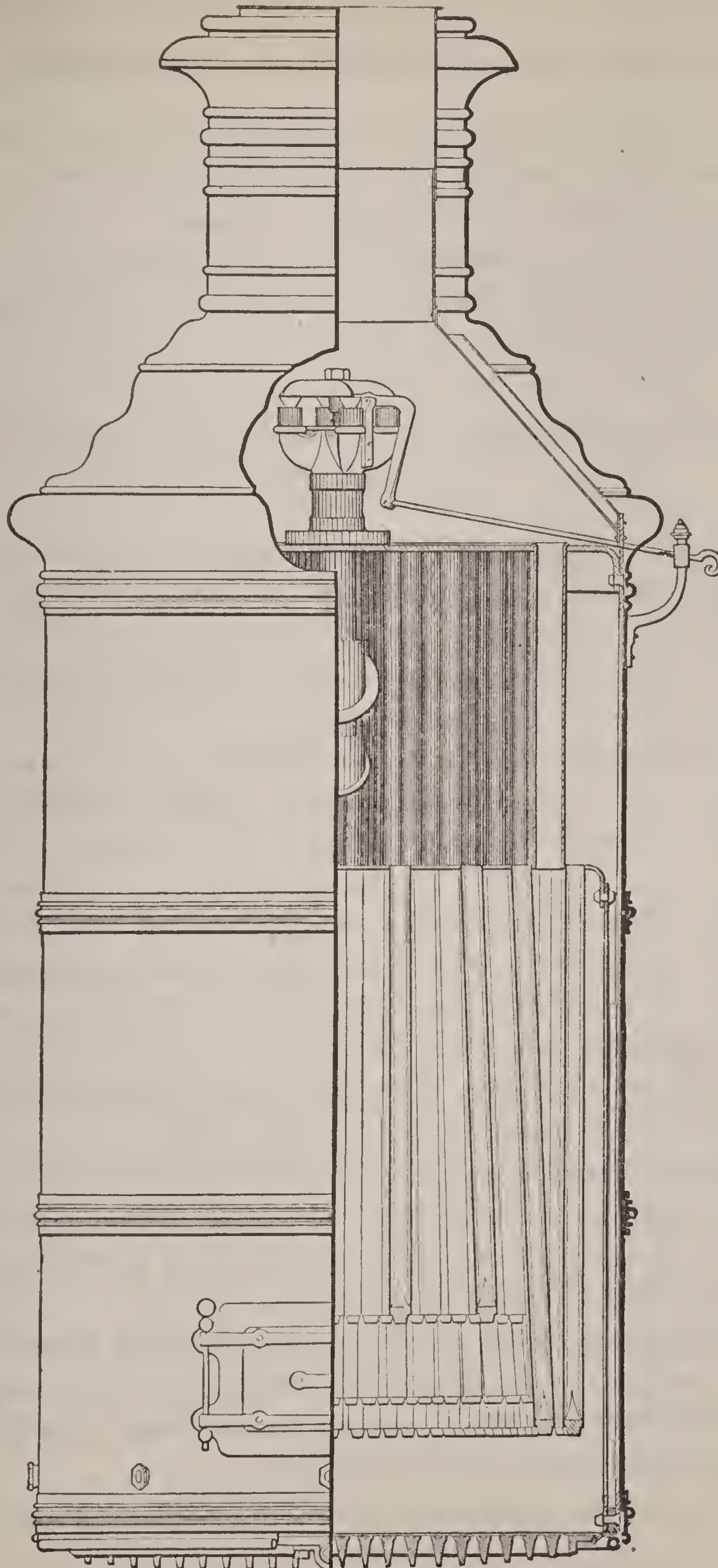
Rule for Flue Boilers.—Multiply $\frac{2}{3}$ of the circumference of the shell in inches by its length in inches; multiply the combined circumference of all the flues in inches by their length in inches; divide the sum of these two products by 144, and the quotient will be the number of square feet of heating surface.

Rule for Cylinder Boilers.—Multiply $\frac{2}{3}$ of the circumference in inches by its length in inches; add to this product the area of one end; divide this sum by 144, and the quotient will be the number of square feet of heating surface.

Rule for Tubular Boilers.—Multiply $\frac{2}{3}$ of the circumference of the shell in inches by its length in inches; multiply the combined circumference of all the tubes by their length in inches. To the sum of these two products add $\frac{2}{3}$ the area of both tube-sheets; from this sum subtract the combined area of all the tubes; divide the remainder by 144, and the quotient will be the number of square feet of heating surface.

Rule *for finding the Heating Surface of Vertical Tubular Boilers, such as are generally used for Fire-engines.*—Multiply the circumference of the fire-box in inches by its height above the grate in inches. Multiply the combined circumference of all the tubes in inches by their length in inches, and to these two products add the area of the lower tube- or crown-sheet, and from this sum subtract the area of all the tubes, and divide by 144. The quotient will be the number of square feet of heating surface in the boiler.

To find the square feet of heating surface in any num-



THE SILSBY VERTICAL STEAM BOILER, described on page 73.

ber of tubes, multiply the circumference of one tube in inches by its length in inches. Multiply this by the whole number of tubes, and divide by 144.

To find the combined area of any number of tubes or flues, multiply the area of one tube by the whole number of tubes, and divide by 144.

DEFINITIONS AS APPLIED TO BOILERS AND BOILER MATERIALS.

Tensile strength is the absolute resistance which a body makes to being torn apart by two forces acting in opposite directions.

Working Strength.—The term "working strength" implies a certain reduction made in the estimate of the strength of materials, so that, when the instrument or machine is put to use, it may be capable of resisting a greater strain than it is expected on the average to sustain.

Safe Working Pressure, or Safe Load.—The safe working pressure of steam-boilers is generally taken as $\frac{1}{5}$ of the bursting pressure, whatever that may be.

Elasticity is that quality which enables a body or boiler to return to its original form after having been distorted or stretched by some extreme force.

Internal Radius.—The internal radius is $\frac{1}{2}$ of the diameter less the thickness of the iron. To find the internal radius of a boiler, take $\frac{1}{2}$ of the external diameter and subtract the thickness of the iron.

Longitudinal Seams.—The seams which are parallel to the length of a boiler are called the longitudinal seams.

Curvilinear Seams.—The curvilinear seams of a boiler are those around the circumference.

TABLE

OF SAFE INTERNAL PRESSURES FOR IRON BOILERS.

Birmingham Wire Gauge.		3/8	00	0	1	2
Thickness of Iron.		.375 3/8	.358 3/8 Scant.	.340 11/32	.300 5/16	.284 9/32
	Dia. In.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.
External Diameter.	24	180.65	172.20	163.29	143.59	135.75
	26	166.34	158.58	150.39	132.28	125.08
	28	154.13	146.96	139.38	122.63	115.95
	30	143.59	136.92	129.88	114.29	108.07
	32	134.40	128.17	121.58	107.01	101.20
	34	126.31	120.47	114.29	100.60	95.14
	36	119.15	113.64	107.81	94.92	89.77
	38	112.75	107.54	102.04	89.84	84.98
	40	107.01	102.07	96.85	85.28	80.67
	42	101.81	97.12	92.11	81.16	76.77
Longitudinal Seams, Single Riveted.	44	97.11	92.63	87.90	77.42	73.24
	46	92.82	88.54	84.02	74.01	70.01
	48	88.89	84.80	80.47	70.89	67.06
	50	85.28	81.36	77.21	68.02	64.35
	52	81.95	78.18	74.20	65.37	61.84
	54	78.87	75.25	71.42	62.92	59.53
	56	76.02	72.53	68.84	60.65	57.38
	58	73.36	70.00	66.43	58.54	55.38
	60	70.89	67.63	64.19	56.57	53.52
	62	68.57	65.43	62.10	54.72	51.78
	64	66.40	63.36	60.14	53.00	50.15
	66	64.37	61.42	58.30	51.38	48.61
	68	62.45	59.59	56.57	49.85	47.17
	70	60.65	57.87	54.93	48.41	45.81
	72	58.95	56.25	53.39	47.06	44.53
	74	57.34	54.71	51.94	45.78	43.32
	76	55.81	53.26	50.56	44.56	42.17
	78	54.37	51.88	49.25	43.41	41.08
	80	53.00	50.57	48.01	42.32	40.04

TABLE—(*Continued*)

OF SAFE INTERNAL PRESSURES FOR IRON BOILERS.

Birmingham Wire Gauge.		3	4	5	6	7	8
Thickness of Iron.		.259 $\frac{1}{4}$ Full.	.238 $\frac{1}{4}$ Scant.	.220 $\frac{7}{32}$	.203 $\frac{6}{32}$ Full.	.180 $\frac{6}{32}$ Scant	.165 $\frac{5}{32}$ Full.
	Dia. In.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.
External	24	123.53	113.31	104.58	96.36	85.28	78.07
Diameter.	26	113.84	104.44	96.40	88.83	78.63	71.99
	28	105.55	96.85	89.40	82.39	72.94	66.79
	30	98.39	90.29	83.36	76.83	68.02	62.29
	32	92.14	84.56	78.07	71.96	63.72	58.35
	34	86.64	79.51	73.42	67.68	59.93	54.89
	36	81.75	75.04	69.29	63.88	56.57	51.81
	38	77.39	71.04	65.60	60.48	53.56	49.06
	40	73.47	67.44	62.29	57.42	50.86	46.58
	42	69.93	64.19	59.29	54.66	48.41	44.35
	44	66.71	61.24	56.57	52.15	46.20	42.32
Long.	46	63.78	58.55	54.08	49.87	44.17	40.46
Seams,	48	61.09	56.09	51.81	47.77	42.32	38.77
Single	50	58.62	53.82	49.72	45.84	40.61	37.21
Riveted.	52	56.35	51.74	47.79	44.07	39.04	35.77
	54	54.24	49.80	46.00	42.42	37.58	34.43
	56	52.28	48.01	44.35	40.90	36.23	33.20
	58	50.46	46.34	42.81	39.48	34.98	32.04
	60	48.77	44.78	41.37	38.15	33.80	30.97
	62	47.18	43.33	40.03	36.91	32.71	29.97
	64	45.69	41.96	38.77	35.75	31.68	29.02
	66	44.30	40.68	37.58	34.66	30.71	28.14
	68	42.99	39.48	36.47	33.64	29.80	27.31
	70	41.75	38.34	35.42	32.67	28.95	26.53
	72	40.58	37.27	34.43	31.76	28.14	25.78
	74	39.48	36.25	33.50	30.89	27.38	25.08
	76	38.43	35.29	32.61	30.08	26.65	24.42
	78	37.44	34.38	31.77	29.30	25.96	23.79
	80	36.49	33.52	30.97	28.56	25.31	23.20

TABLE—(*Continued*)

OF SAFE INTERNAL PRESSURES FOR IRON BOILERS.

Birmingham Wire Gauge.		$\frac{3}{8}$	00	0	1	2
Thickness of Iron.		.375 $\frac{3}{8}$	:358 $\frac{3}{8}$ Scant.	.340 $\frac{11}{32}$	.300 $\frac{5}{16}$	.284 $\frac{9}{32}$
	Dia. In.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.
External	24	225.81	215.26	204.12	179.49	169.67
Diameter.	26	207.93	198.23	187.91	165.35	156.34
	28	192.66	183.70	174.23	153.28	144.94
	30	179.49	171.15	162.35	142.86	135.09
	32	168.00	160.21	151.98	133.76	126.49
	34	157.89	150.58	142 86	125.75	118.93
	36	148.94	142.05	134.77	118.64	112.21
	38	140.94	134.43	127.55	112.30	106.22
	40	133.76	127.58	121.06	106.60	100.83
Longitudinal	42	127.27	121.40	115.20	101.45	95.96
Seams,	44	121.39	115.79	109.88	96.77	91.55
Double	46	116.02	110.68	105.03	92.51	87.52
Riveted,	48	111.11	106.00	100.59	88.61	83.83
Curvilinear	50	106.19	101.70	96.51	85.02	80.43
Seams,	52	102.44	97.73	92.75	81.71	77.33
Single	54	98.59	94.10	89.27	78.69	74.41
Riveted.	56	95.02	90.66	86.04	75.81	71.73
	58	91.70	87.49	83.04	73.17	69.23
	60	88.61	84.54	80.24	70.71	66.90
	62	85.71	81.78	77.63	68.40	64.72
	64	83.00	79.17	75.17	66.25	62.68
	66	80.46	76.78	72.87	64.22	60.77
	68	78.07	74.47	70.71	62.31	58.96
	70	75.81	72.34	68.67	60.52	57.26
	72	73.68	70.31	66.74	58.82	55.66
	74	71.67	68.39	64.92	57.22	54.15
	76	69.77	66.60	63.19	55.70	52.77
	78	67.96	64.85	61.56	54.26	51.35
	80	66.25	63.22	60.01	52.90	50.06

TABLE—(*Continued*)

OF SAFE INTERNAL PRESSURES FOR IRON BOILERS.

Birmingham Wire Gauge.		3	4	5	6	7	8
Thickness of Iron.		.259 ¼ Full.	.238 ¼ Scant.	.220 $\frac{7}{32}$	.203 $\frac{6}{32}$ Full.	.180 $\frac{6}{32}$ Scant	.165 $\frac{5}{32}$ Full
	Dia. In.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.	lbs. per sq. in.
External	24	154.42	141.64	130.73	120.45	106.60	97.59
Diameter.	26	142.30	130.54	120.50	111.04	98.21	89.99
	28	131.94	121.06	111.76	102.99	91.17	83.48
	30	122.99	112.86	104.19	96.03	85.02	77.86
	32	116.32	105.70	97.59	89.95	79.65	72.94
	34	108.30	99.39	91.78	84.60	74.91	68.61
	36	102.19	93.80	86.61	79.84	70.71	64.76
	38	96.74	88.80	82.00	75.60	66.95	61.32
	40	91.84	84.30	77.86	71.78	63.57	58.23
	42	87.41	80.24	74.11	68.33	60.52	55.44
	44	83.39	76.56	70.71	65.19	57.75	52.90
Long.	46	79.72	73.19	67.60	62.33	55.22	50.58
Seams,	48	76.37	70.11	64.76	59.71	52.90	48.46
Double	50	73.28	67.28	62.11	57.31	50.77	46.51
Riveted.	52	70.43	64.67	59.74	55.08	48.80	44.71
Curvil.	54	67.80	62.25	57.51	53.40	46.98	43.04
Seams,	56	65.35	60.01	55.44	51.12	45.29	41.50
Single	58	63.07	57.92	53.51	49.35	43.72	40.06
Riveted.	60	60.96	55.98	51.71	47.69	42.25	38.71
	62	58.98	54.16	50.03	46.14	40.88	37.46
	64	57.12	52.45	48.46	44.69	39.60	36.28
	66	55.37	50.85	46.98	43.33	38.39	35.18
	68	53.73	49.35	45.59	42.05	37.26	34.14
	70	52.19	47.93	44.28	40.84	36.19	33.16
	72	50.73	46.59	43.04	39.70	35.18	32.23
	74	49.35	45.32	41.87	38.62	34.22	31.36
	76	48.04	44.11	40.76	37.60	33.32	30.53
	78	46.80	42.98	39.71	36.63	32.46	29.74
	80	45.62	41.90	38.71	35.71	31.64	28.99

LONGITUDINAL AND CURVILINEAR STRAINS.

The force tending to rupture a cylinder along the curved sides depends upon the diameter of the cylinder and pressure of steam ; and we may therefore consider the total pressure sustained by the sides to be equal to the diameter × pressure per unit of surface × length of cylinder, neglecting any support derivable from the heads, which, in practice, depends on the length.

It must be understood that the strain on a boiler subjected to internal pressure transversely, is exactly double what it is longitudinally ; or, in other words, the strain on the longitudinal seams is double that on the curvilinear. No matter what the diameter of a boiler may be, the transverse pressure tending to tear it asunder will always be double the pressure exerted on the curvilinear seams.

HEAT.

It would be difficult to over-estimate the importance of the part played by heat, both on a grand scale in the laboratory of nature, and on a minor scale, in the domain of human art and science. In the former respect, it is not only an essential condition of the existence of life on this planet, but also the prime agent in putting in motion most of the physical changes which take place at the earth's surface. In the latter respect it must be regarded not only as furnishing man with the chief means he possesses of imitating nature, and moulding and modifying natural productions to his wants, but also as bestowing on him the ability to generate and apply at pleasure a force equally stupendous and easy to control.

Heat is one form of mechanical power, or, more properly, a given quantity of heat is the equivalent of a de-

terminate amount of mechanical power; and as heat is capable of producing power, so, contrariwise, power is capable of producing heat. As it becomes necessary to have a standard for measuring the amount of heat absorbed or evolved during any operation, in this country the standard unit is the amount of heat necessary to raise the temperature of a pound of water 1° Fah., or from 32° to 33° Fah.

Specific Heat.—Different bodies require different quantities of heat to effect in them the same change of temperature. The capacity of a body for heat is termed its "specific heat," and may be defined as the number of units of heat necessary to raise the temperature of 1 pound of that body 1° Fah. When a substance is heated it expands, and its temperature is increased. It is evident, therefore, that heat is required both to raise the temperature and to increase the distance between the particles of the substance.

The heat used in the latter case is converted into interior work, and is not sensible to the thermometer; but it will be given out, if the temperature of the substance is reduced to the original point. Thus, while heat is apparently lost, it is only stored up, ready to do work, and the substance possesses a certain amount of latent and inherent energy, or possibility of doing work.

Now, as different substances vary greatly in their molecular constitution, expanding and contracting the same amount with widely differing degrees of force, it is to be expected that the same quantity of heat that will raise one substance to a given temperature, will exert a different effect upon another body, which may require a greater or less degree of heat to produce the same result; and we find in practice that such is the case.

The condition of heat is measured as a quantity, and

its amount in different bodies and under different circumstances is compared by means of the changes in some measurable phenomenon produced by its transfer or disappearance. In so using changes of temperature, it is not to be taken for granted that equal differences of temperature in the same body correspond to equal quantities of heat. This is the case, indeed, for perfectly gaseous bodies; but that is a fact only known by experiment.

On bodies in other conditions, equal differences of temperature do not exactly correspond to equal quantities of heat. To ascertain, therefore, by an experiment on the changes of temperature of any given substances, what proportion two quantities of heat bear to each other, the only method which is of itself sufficient, in the absence of all other experimental data, is the comparison of the weights of that substance which are raised from the same low temperature to a high or fixed temperature.

The Unit of Heat.—The unit of heat, or the thermal unit employed, is the quantity of heat, as before stated, that will raise 1 pound of pure water 1° Fah., or from 39° to 40° Fah. The reason for selecting that part of the scale which is nearest the temperature of the greatest density of water, is because the quantity of heat corresponding to an interval of one degree in a given weight of water is not exactly the same in different parts of the scale of temperature.

Latent Heat.—Latent heat means a quantity of heat which has disappeared, having been employed to produce some change other than elevation of temperature. By exactly reversing that change, the quantity of heat which had disappeared is reproduced.

When a body is said to possess or contain so much latent heat, what is meant is simply this: that the body is in a condition into which it was brought from a former

and different condition by transferring to it a quantity of heat which did not raise its temperature, the change of condition being different from change of temperature, and that by restoring the body to its original condition in such a manner as exactly to reverse the former process, the quantity of heat formerly expended may be reproduced in the body and transferred to other bodies.

When a body passes from the solid to the liquid state, as ice to water, its temperature remains stationary, or nearly so, at a certain melting point, during the whole operation of melting; and in order to cause that operation to continue, a quantity of heat must be transferred to the substance melted, a certain amount for each unit of weight of the substance. But this heat does not raise the temperature of the substance, but disappears in causing its condition to change from the solid to the liquid state.

When a substance passes from the liquid to the solid state, as water being converted to ice, its temperature remains stationary, or nearly so, during the whole operation of freezing; a quantity of heat equal to the latent heat of fusion is produced in the body; and in order that the operation of freezing may go on, that amount of heat must be transferred from that body to some other substance.

Sensible Heat.—Sensible heat is that which is sensible to the touch or measurable by the thermometer.

Mechanical Equivalent of Heat.—The mechanical equivalent of heat is the amount of work performed by the conversion of one unit of heat into work. This has been determined to be equal in amount to the work required to raise 772 pounds one foot high, or one pound 772 feet high. And as heat and work are mutually convertible, if a body weighing one pound, after falling through a height of 772 feet, were to have its motion suddenly arrested, it

would develop sufficient heat to raise the temperature of a pound of water one degree.

If a pound of water, at a temperature of 212° Fah., is converted into steam, the latter will possess a volume of about $27\frac{1}{4}$ cubic feet. Now, suppose that the water is evaporated in a long cylinder of exactly one foot cross section, open to the atmosphere at the top, when all the water in the cylinder has disappeared, there will be a column of steam $27\frac{1}{4}$ feet high, which has risen to this height against the pressure of the atmosphere.

The pressure of the air being nearly 15 pounds per square inch, the pressure per square foot is 2115 pounds, and the external work performed by the water, while being converted into steam, will be an amount required to raise 2115 pounds to a height of $27\frac{1}{4}$ feet, or about 57,644 foot-pounds. Now, since 772 foot-pounds of work require one unit of heat, the external work will take up 57,644 divided by 772, which equals 74.64 units of heat. But it has been shown that the total number of units of heat required to change water into steam is about 968 (more accurately, 966.6). Hence the internal work will be equal to an amount developed by the conversion of 966.6 less 74.67, which equals 891.93, units of heat into work, and this will equal 891.93, multiplied by 772, which equals 688,569 foot-pounds.

Mechanical Theory of Heat.—The mechanical theory of heat is now generally adopted It is based on the assumption that heat and work are mutually convertible, and on this theory can be explained what becomes of the latent heat. All solid bodies are supposed to be made up of molecules, which are not in contact, but are prevented from separating by a force called cohesion. If a body is heated to a sufficient temperature, the force of expansion becomes equal to that of cohesion, and the body is lique-

fied; and if still more heat is applied, the force of expansion exceeds that of cohesion, and the liquid becomes vapor. But in each of these changes work is performed, and the heat that is supplied is converted into work. For instance, if ice is at a temperature of 32°, and heat is applied, this is converted into the work that is developed in changing the ice into water, and we say that heat becomes latent; again, when water is at 212°, and we continue to apply heat, this is converted into the work that must be done in converting the water into steam.

Dynamic Equivalent of Heat.—It is a matter of everyday observation, that heat, by expanding bodies, is a source of mechanical energy; and conversely, that mechanical energy, being expended either in compressing bodies or in friction, becomes a source of heat. In all other cases in which heat is produced by the expenditure of mechanical energy, or in which mechanical energy is produced by the expenditure of heat, some other change is produced besides that which is principally considered; and this prevents the heat and the mechanical energy from being exactly equivalent.

Power of Expansion by Heat.—When bodies expand, the molecules of which they are composed are pushed farther asunder by the oscillatory motion communicated to them. The heat may be described as entering the substance and immediately setting to work to separate the particles. The power or energy it exerts to do this is immense.

Molecular or Atomic Force of Heat.—All molecules are under the influence of two opposite forces. The one, viz., molecular attraction, tends to bring them together; the other, viz., heat, tends to separate them: its intensity varies with its velocity of vibration. Molecular attraction is only exerted at infinitely small distances, and is

known under the name of cohesion, affinity, and adhesion.

Total or Actual Heat.— If, when a substance, by the expenditure of energy in friction, is brought from a condition of total privation of heat to any particular condition of heat, we subtract from the total energy so expended, first, the mechanical work performed by the action of the substance on external bodies, through changes of its volume, during such heating, secondly, the mechanical work due to the mutual action between the particles of the substance itself during such heating, the remainder will represent the energy which is employed in making the substance hot.

Communication of Heat.— Heat may be communicated from a hot body to a cold one in three ways,— by radiation, conduction, and circulation. The rapidity with which heat radiates varies, other things being equal, as the square of the temperature of the hot body is in excess of the temperature of the cold one; so that a body, if made twice as hot, will lose a degree of temperature in one-fourth of the time; if made three times as hot, it will lose a degree of temperature in one-ninth of the time, and so on in all other proportions.

Transmission of Heat.—Tredgold and others have made experiments to ascertain the rate at which heat is transferred from metal to gases and from gases to metal. Other things being equal, it has been found that the rate of transferrence is as the difference of temperature. But in practice the conditions are different from those in the experiment; generally, in experiments, the air has been still, and the gases moving under natural draught; but in locomotive practice, the velocity of the gases is so great as to render the results of most experiments inapplicable.

Effects of Heat on the Circulation of Water in Boilers.

— As the particles of water rise heated from the bottom of the boiler, other particles necessarily subside into their places, and it is a point of considerable importance to ascertain the direction in which the currents approach the plate to receive heat. A particle of water cannot leave the heated plate until there is another particle at hand to occupy its position; therefore, unless a due succession in the particles is provided for, the plate cannot get rid of its heat, and the proper formation of steam is retarded. But it must be understood that vaporizing does not depend on the quantity of heat applied to the plate, but on the quantity of heat abstracted from it by the particles of water.

Medium Heat.—The medium heat of the globe is placed at 50°; at the torrid zone, 75°; at moderate climates, 50°; near the Polar regions, 36° Fah. The extremes of natural heat are from 70° to 120°; of artificial heat, 91° to 36000° Fah.

LATENT HEAT OF VARIOUS SUBSTANCES.

	Fah.		Fah.
Ice	140°	Steam	990°
Sulphur	144	Vinegar	875
Lead	162	Ammonia	860
Beeswax	176	Alcohol	442
Zinc	493	Ether	301

TABLE OF THE RADIATING POWER OF DIFFERENT BODIES.

Water	100°	Blackened tin	100°
Lamp-black	100	Clean "	12
Writing-paper	100	Scraped "	16
Glass	90	Ice	85
India-ink	88	Mercury	20
Bright lead	19	Polished iron	15
Silver	12	Copper	12

TABLE

SHOWING THE EFFECTS OF HEAT UPON DIFFERENT BODIES.

	Fah.		Fah.
Cast-iron, thoroughly smelted	2754°	Lead melts	594°
Fine gold melts	1983	Bismuth "	476
Fine silver "	1850	Tin "	421
Copper "	2160	Tin and Bismuth, equal parts, melt	283
Brass "	1900	Tin, 3 parts, Bismuth 5, and Lead 2 parts, melt	212
Red heat, visible by day	1077	Alcohol boils	174
Iron red-hot in twilight	884	Ether "	98
Common fire	790	Human blood (heat of)	98
Iron, bright red in the dark	752	Strong wine freezes	20
Zinc melts	740	Brandy "	7
Quicksilver boils	630	Mercury melts	39
Linseed oil	600		

CALORIC.

The ordinary application of the word *heat* implies the sensation experienced on touching a body hotter, or of a higher temperature; whilst the term *caloric* provides for the expression of every conceivable existence of temperature. Caloric is usually treated as if it were a material substance; but, like light and electricity, its true nature has yet to be determined.

Caloric passes through different bodies with different degrees of velocity. This has led to the division of bodies into *conductors* and *non-conductors* of caloric; the former includes such bodies as metals, which allow caloric to pass freely through their substance, and the latter comprises those which do not give an easy passage through it, such as stones, glass, wood, charcoal, etc.

Radiation of Caloric. — When heated bodies are exposed to the air, they lose portions of their heat by projections in right lines into space from all parts of their surface. Radiation is effected by the nature of the surface

of the body; thus, black and rough surfaces radiate and absorb more heat than light and polished surfaces. Bodies which radiate heat best, absorb it best.

Reflection of caloric differs from radiation, as the caloric is in this case reflected from the surface without entering the substance of the body. Hence, the body which radiates, and consequently absorbs most caloric, reflects the least, and *vice versa*.

Latent caloric is that which is insensible to the touch, or incapable of being detected by the thermometer. The quantity of heat necessary to enable ice to assume the fluid state, is equal to that which would raise the temperature of the same weight of water 140° Fah., in which case an equal quantity of heat is set free from water when it assumes the solid form.

Sensible caloric is free and uncombined, passing from one substance to another, affecting the senses in its passage, determining the height of the thermometer, and giving rise to all the results which are attributed to this active principle.

Evaporation produces cold, because caloric must be absorbed in the formation of vapor (a large quantity of it passing from a sensible to a latent state), the capacity for heat of the vapor formed being greater than that of the fluid from which it proceeds.

Caloric is, therefore, either free and sensible, or latent and insensible. Caloric is known to be the cause of fluidity; and the absence of caloric, the cause of solidity. If heat be applied to ice or iron, it becomes fluid; if exposed to cold, it resumes its solid form.

COMBUSTION.

Combustion is, strictly speaking, the development of heat by chemical combination; but though this may take place from the union of a variety of bodies, the omnipresent agent, oxygen, plays so vastly more important a part than all others in the disengagement of light and heat, that the act of its combination with other bodies is pre-eminently entitled combustion.

Since combustion, in the ordinary acceptation of the word, is the only means had recourse to in the arts for the development of artificial heat, perfect combustion may, for our purpose, be defined to be — the combination of a combustible body with the largest measure of oxygen with which it is capable of uniting. In fact, for all practical purposes, the fuel, or combustible body, employed may be regarded as composed exclusively of carbon and hydrogen; so that our inquiry becomes narrowed down to the combinations of oxygen with these two elementary substances.

No substance in nature is combustible of itself, whatever the degree of heat to which it may be exposed; and it can be ignited only when in presence of or in mechanical combination with air, or its vital element, oxygen, because combustion is continuous ignition, and may only be caused by maintaining in the combustible mixture the heat necessary to ignite it. Chemical combination in every case is accompanied by the production of heat; every decomposition, by a disappearance of heat equal in amount to that which is produced by the combination of the elements which are to be separated.

When a complex chemical action takes place in which various combinations and decompositions occur simultaneously, the heat obtained is the excess of the heat produced by the combinations above the heat, which disap-

pears in consequence of the decompositions. Sometimes the heat produced is subject to a further deduction, on account of heat which disappears in melting or evaporating some of the substances which combine either before or during the act of combination.

Substances combine chemically in certain proportions only. To each of the substances known in chemistry, a certain number can be assigned, called its chemical equivalent, having these properties: — 1st. That the proportions by weight in which substances combine chemically can all be expressed by their chemical equivalents, or by simple multiples of their chemical equivalents. 2d. That the chemical equivalent of a compound is the sum of the chemical equivalents of its constituents.

Chemical equivalents are sometimes called atomic weights or atoms, in accordance with the hypothesis that they are proportionate to the weights of the supposed atoms of bodies, or smallest similar parts into which bodies are assumed to be divisible by known forces. The term *atom* is convenient from its shortness, and can be used to mean "chemical equivalent," without necessarily affirming or denying the hypothesis from which it is derived, which, how probable soever it may be, is, like other molecular hypotheses, incapable of absolute proof.

The chief elementary combustible constituents of ordinary fuel are carbon and hydrogen. Sulphur is another combustible constituent of ordinary fuel, but its quantity is small and its heating power of no practical value. Coal is composed, so far as combustion is concerned, of solid carbon and a gas consisting of hydrogen and carbon. When the coal is heated, it first discharges its gas; the solid carbon left then ignites in presence of oxygen, and will retain the temperature necessary to combustion so long as oxygen is applied.

The Ingredients of Fuel.—Fixed or free carbon, which is left in the form of charcoal or coke after the volatile ingredients of the fuel have been distilled away, burns either wholly in the solid, or partly in the solid or gaseous state; the volatile ingredients being first dissolved by previously formed carbonic acid, as already explained.

Hydrocarbons are such substances as gas, pitch, tar, naphtha, etc., all of which must pass into the gaseous state before being burned. If mixed on their first issuing from among the burning carbon with a large quantity of air, these inflammable gases are completely burned, with a transparent blue flame, producing carbonic acid and steam.

Mixture of Fuel and Air.— In burning charcoal, coke, and coals with a small proportion only of hydrocarbons, a supply of air sufficient for complete combustion will enter from the ash-pit through the bars of the grate, provided there is sufficient draught, and that care is taken to distribute the fresh fuel evenly over the fire, and in moderate quantities at a time.

Available Heat of Combustion.— The available heat evolved by the combustion of one pound of a given sort of fuel is that part of the total heat of combustion which is communicated to the body, to heat which the fuel is burned.

Anthracite Coal.—The chemical composition of anthracite coal is similar to charcoal, from which it differs chiefly in its form, being very hard and compact, and in the greater quantity of ashes which it contains. It is, like charcoal, unaltered in form after exposure to the strongest heat; even after passing through a blast furnace, it has equally as sharp edges, and is in form exactly as it was before.

COMPOSITION OF DIFFERENT KINDS OF ANTHRACITE COAL.

	Carbon.	Volatile Matter.	Ashes.	Specific Gravity.
Lehigh Coal	88.50	7.50	4.00	......
Schuylkill Coal	92.07	5.03	2.90	1.57
Pottsville	94.10	1.40	4.50	1.50
Pinegrove	79.57	7.15	3.28	1.54
Wilkesbarre	88.90	7.68	3.49	1.40
Carbondale	90.23	7.07	2.70	1.40

The analysis of anthracite shows good coal of that class to be composed of 90.45 carbon, 2.43 hydrogen, 2.45 oxygen, some nitrogen, and 4.67 ashes. The ashes generally consist, like those of bituminous coal, of silex, alumina, oxide of iron, and chlorides, which generally evaporate and condense on cold objects in the form of while films.

Anthracite is not so inflammable as either dry wood or bituminous coal, but it may be made to burn quite as vividly as either, by exposing it to a strong draugh. or in a large mass to the action of the air.

The Quantity of Air required for the Combustion of Anthracite Coal.—In view of the quantity of oxygen required to unite chemically with the various constituents of the coal, we find that in 100 pounds of anthracite coal, consisting of 91 per cent. of carbon and 9 per cent. of the other matter, it will be necessary to have 243.84 pounds of oxygen, since to saturate a pound of carbon by the formation of carbonic acid requires $2\frac{2}{3}$ pounds of oxygen. To saturate a pound of hydrogen in the formation of water requires 8 pounds of oxygen; hence, 3.46 pounds of hydrogen will take 27.68 pounds of oxygen for its saturation. If, then, we add 243.84 pounds of oxygen for its satura-

tion, 271.52 pounds of oxygen are required for the combustion of 100 pounds of coal.

A given weight of air contains nearly 23.32 per cent. of oxygen; hence, to obtain 271.52 pounds of oxygen, we must have about four times that quantity of atmospheric air, or, more accurately, 1164 pounds of air are required for the combustion of 100 pounds of coal. A cubic foot of air at ordinary temperatures weighs about .075 pound; so that 100 pounds of coal require 15,524 cubic feet of air, or one pound of coal requires about 155 cubic feet of air, supposing every atom of the oxygen to enter into combination. If, then, from one-third to one-half of the air passes unconsumed through the fire, an allowance of 240 cubic feet of air for each pound of coal will be a small enough allowance to answer all practical requirements, and in some cases as many as 320 cubic feet will be required.

The Evaporative Efficiency of a Pound of Anthracite Coal.— The evaporative efficiency of a pound of carbon has been found, experimentally, to be equivalent to that power which is necessary to raise 14,000 pounds of water through one degree, or 14 pounds of water through 1000 degrees, supposing the whole heat generated to be absorbed by the water.

Now, if the water be raised into steam from a temperature of 60°, then 1118.9° of heat will have to be imparted to it to convert it into steam of 15 pounds pressure per square inch; 14,000 divided by 1118.9 equals 12.5 pounds will be the number of pounds of water, therefore, which a pound of carbon can raise into steam of 15 pounds pressure from a temperature of 60°. This, however, is a considerably larger result than can be expected in practice.

Bituminous Coal.— Under this class we range all that mineral coal which forms coke, that is, which swells upon

being exposed to heat, burns with a bright flame, and blazes. After the flame disappears there remains a spongy, porous mass — coke — which burns without flame, like charcoal. In its composition we find chiefly carbon, oxygen, hydrogen, nitrogen, sulphur, and ashes, with a little water, which has been absorbed by the crevices.

The following table shows the comparative composition of various sorts of mineral fuel: —

	Carbon.	Hydrogen.	Oxygen and Nitrogen.	Ashes.
Turf	58.09	5.93	31.37	4.61
Brown Coal	71.71	4.85	21.67	1.77
Hard Bituminous Coal	82.92	6.49	10.86	0.13
Cannel Coal	83.75	5.66	8.04	2.55
Cooking or Baking Coal	87.95	5.24	5.41	1.40
Anthracite	91.98	3.92	3.16	0.94

An essential condition in forming coke is that the coal, on being heated, swells and changes into irregular, spongy masses, which adhere intimately together. This operation is designed to expel sulphur and hydrogen, and form a coal which is not altered by heat. The sulphur cannot be entirely separated from coke, or from carbon, no matter how high the heat may be; nor can all the hydrogen be removed from carbon by simply heating the compound. If oxygen is admitted to these combinations, both sulpnur and hydrogen may be almost entirely expelled, that is, provided the oxygen is not introduced under too high or too low a heat.

The most important point, and one which has a direct bearing upon the value of coal, is the quantity of heat which it can evolve in combustion. If we assume that the quantity of ashes is equal in the four substances mentioned

below, that is, 5 per cent. in each, and suppose further that pine charcoal furnishes 100 parts of heat, the following table shows the quantity which must be liberated in their perfect combustion:

Kind of Coal.	Carbon.	Hydrogen.	Water.	Quantity of Heat.
Brown Coal........................	69	3	23	78
Cooking Coal.....................	75	4	16	87
" "	78	4	13	90
Anthracite Coal..................	85	3	7	94
Pure Carbon.......................	100	...	...	100

Bituminous coal, like all other fuel, is a compound substance, which may be decomposed by heat into several distinct elements—generally five or six, at least. So far as relates to combustion, we are concerned principally with but two of these, viz., solid carbon, represented by coke, and hydrogen, generally known under the indefinite term of "gas." These two elements contain principally the full heating qualities of the coal. The carbon, so long as it remains as such, is always solid and visible. The hydrogen, when driven from the coal by heat, carries with it a portion of the carbon, the gaseous compound being known as carburetted hydrogen. A ton of 2000 pounds of average bituminous coal contains, say 1600 pounds, or 80 per cent. of carbon, 100 pounds, or 5 per cent. of hydrogen, and 300 pounds, or 15 per cent. of oxygen, nitrogen, sulphur, sand, and ashes. But if this coal be coked, the 100 pounds of hydrogen driven off by heat will carry about 300 pounds of carbon in combination with it, making 400 pounds, or nearly 1000 cubic feet of carburetted hydrogen gas, and 1300 pounds of carbon (65 per cent. of the original coal) will be left. With the earthy matter, ashes, sulphur, etc., retained with it, the coke will weigh but about

1350 or 1400 pounds,— 67½ to 70 per cent. of the original coal. The only proportions in which carbon and hydrogen combine with air in combustion are these: For every pound of carbon (pure coke), 12 pounds (equal to 159½ cubic feet) of air are required to combine intimately with it. For every pound of hydrogen, 36 pounds (equal to 478½ cubic feet) of air are required to be similarly combined. Thus for every pound of carburetted hydrogen gas, being one-fourth pound of hydrogen and three-fourths of a pound of carbon, 18 pounds (equal to 239¼ cubic feet) of air are required to be combined with it.

These are the elements and their combining proportions that have to be dealt with in the furnace of a steam-boiler. For every 2000 pounds of coal burned, the 400 pounds of carburetted hydrogen, which constitute the "gas," require 95,700 cubic feet of atmospheric air at ordinary temperature, and the 1300 pounds of solid carbon require 207,350 cubic feet of air. Practically, the gas from a ton of ordinary bituminous coal requires 100,000 cubic feet of air for its combustion, while the remaining coke requires 200,000 feet.

The heating value of any combustible is exactly proportional to the quantity of air with which it will combine in combustion. Hence hydrogen, which combines with three times the quantity of air (oxygen) which would be taken up by carbon, has, for equal weights, three times the heating value. Thus, the 100 pounds of pure hydrogen in a ton of coal have the same heating efficiency as that due to 300 pounds of the remaining carbon or pure coke. It will now be seen that complete combustion cannot produce smoke, since smoke contains a quantity of unburnt matter, and is in itself a proof of incomplete combustion. The products of perfect combustion are invisible—being for carbon and oxygen, carbonic acid; and for hydrogen and oxygen, invisible steam, which condenses into water.

The admission of heated air to furnaces or fire-boxes of locomotives can be of no practical value, since for every 493° Fah. of heat added, its original bulk or volume is doubled; trebled at 1010° Fah., and at 3000° Fah. the heated air in the interior of the furnace has six times its original volume. This makes it more unmanageable, and as its contained oxygen remains the same in weight, its mixture with the gas becomes more difficult, while, when mixed, it can do only the same work as before.

Waste of Unburnt Fuel.—This generally arises from the brittleness of the fuel, combined with want of care on the part of the fireman, from which cause the fuel is made to fall into small pieces, which escape between the grate-bars into the ash-pit, and are lost. It is almost impossible to estimate the loss of fuel occasioned by carelessness and bad firing; but the amount which is unavoidable, even with care and good firing, has been ascertained by experiment to range from $2\frac{1}{2}$ to 3 per cent. of the fuel consumed.

TABLE

SHOWING THE TOTAL HEAT OF COMBUSTION OF VARIOUS FUELS.

SORT OF FUEL.	Equivalent in pure Carbon.	Evaporative power in lbs. water from 212° Fah.	Total heat of combustion in lbs. water heated 1° Fah.
Charcoal	0.93	14.00	13500
Charred Peat	0.80	12.00	11600
Coke — good	0.94	14.00	13620
" mean	0.88	13.20	12760
" bad	0.82	12.30	11890
COAL — Anthracite	1.05	15.75	15225
Hard Bituminous — hardest	1.06	15.90	15370
" " softest	0.95	14.25	13775
Cooking coal	1.07	16.00	15837
Canning coal	1.04	15.60	15080
Long flaming splint coal	0.91	13.65	13195
Lignite	0.81	12.15	11745
PEAT.—Perfectly air-dry	0.66	10.00	9660
Containing 25 per ct. water	......	7.25	7000
WOOD.—Perfectly air-dry	0.50	7.50	7245
Containing 20 per ct. water	......	5.80	5600

TABLE

SHOWING THE NATURE AND VALUE OF SEVERAL VARIETIES OF AMERICAN COAL AND COKE, AS DEDUCED FROM EXPERIMENTS BY PROFESSOR JOHNSON, FOR THE UNITED STATES GOVERNMENT.

Designation of Fuel.	Specific gravity.	Weight per cubic foot.	Lbs. of steam from water at 212° by 1 lb. of fuel.	Lbs. of steam from water at 212° by 1 cub. ft. of fuel.	Weight of clinker from 100 lbs. of fuel.	No. of cub. ft. required to stow a ton.
BITUMINOUS.						
Cumberland, *maximum*	1.313	52.92	10.7	573.3	2.13	42.3
" *minimum*	1.337	54.29	9.44	532.3	4.53	41.2
Blossburgh	1.324	53.05	9.72	522.6	3.40	42.2
Midlothian, *screened*	1.283	45.72	8.94	438.4	3.33	49.0
" *average*	1.294	54.04	8.29	461.6	8.82	41.4
Newcastle	1.257	50.82	8.66	453.9	3.14	44.0
Pictou	1.318	49.25	8.41	478.7	6.13	45.0
Pittsburgh	1.252	46.81	8.20	384.1	.94	47.8
Sydney	1.338	47.44	7.99	386.1	2.25	47.2
Liverpool	1.262	47.88	7.84	411.2	1.86	46.7
Clover Hill	1.285	45.49	7.67	359.3	3.86	49.2
Cannelton, Ia.	1.273	47.65	7.34	360.0	1.64	47.0
Scotch	1.519	51.09	6.95	369.1	5.63	43.8
ANTHRACITE.						
Peach Mountain	1.464	53.79	10.11	581.3	3.03	41.6
Forest Improvement	1.477	53.66	10.06	577.3	.81	41.7
Beaver Meadow No. 5	1.554	56.19	9.88	572.9	.60	39.8
Lackawanna	1.421	48.89	9.79	493.0	1.24	45.8
Beaver Meadow No. 3.	1.610	54.93	9.21	526.5	1.01	40.7
Lehigh	1.590	55.32	8.93	515.4	1.08	40.5
COKE.						
Natural Virginia	1.323	46.64	8.47	407.9	5.31	48.3
Midlothian	....	32.70	8.63	282.5	10.51	68.5
Cumberland	....	31.57	8.99	284.0	3.55	70.9

TABLE

SHOWING SOME OF THE PROMINENT QUALITIES IN THE PRINCIPAL AMERICAN WOODS.

Species.	Specific gravity, green.	Specific gravity, air-dried.	Specific gravity, kiln-dried.	Degrees of heat which may be generated.	Percentage of charcoal.	Quantity of heat as to volume.	Weight of one cord in pounds.	Relative value as fuel.
Hickory......	....	....	....	3000	44.69	25	4496	1.00
White Oak..	1.07	0.71	0.66	3000	21.62	25	3821	0.81
Black Oak...	....	....	....	3000	23.80	25	3254	0.71
Red Oak.....	1.05	0.68	0.66	3000	22.43	25	3254	0.69
Beech.........	0.98	0.59	0.58	3000	32.36	25	3236	0.65
Birch.........	0.90	0.63	0.57	3000	....	25	....	....
Maple	0.90	0.64	0.61	3000	27.00	25	2700	0.57
Yellow Pine	.. ..	....	....	2800	24.63	23	2463	0.54
Chestnut.....	....	....	....	3000	25.25	25	2333	0.52
Pitch Pine...	....	....	....	2800	19.04	23	1904	0.43
White Pine..	0.87	0,47	0.38	2800	18.68	23	1868	0.42

TABLE

SHOWING THE RELATIVE PROPERTIES OF GOOD COKE, COAL, AND WOOD.

Name of Fuel.	Weight per cubic foot, in pounds.	Degrees of heat generated.	Percentage of carbon in the fuel.	Economical bulk, or cubic feet required to stow one ton.	Economic or stowage weight per cubic foot.	Cubic feet of air to evaporate one pound of water.	Equivalent economic bulk, to evaporate same weight of water.	Weight of water evaporated per pound of fuel in ordinary practice.	Relative value as fuel, disregarding actual cost.
Coke............	63	4300	95	80	28	22.4	13	8½	100
Coal....	80	4000	88	44	51	32.0	10	6	71
Wood...........	30	2800	20	107	21	16.0	60	2½	29

ENTIRE COAL PRODUCTIONS OF THE WORLD.

The entire annual coal yield of the world is estimated at 250,000,000 of tons, and its value exceeds that of all the other ores mined. The total coal yield of England, in 1871, was valued at $92,000,000, while that of all other mineral products, including refractory clays, mineral salts, phosphorites, etc., did not exceed $62,000,000. In Germany and France, the same excess in favor of coal also appears.

The aggregate production of 250,000,000 tons in 1872 was made up by the various countries in the world contributing as follows: Great Britain, 123,000,000; United States, 40,000,000; Germany, 40,000,000; France, 15,900,000; Belgium, 15,600,000; Austria and Hungary, 10,000,000; Spain, 1,000,000; Russia, 800,000; and the English Colonies, China, Chili, and Japan, 3,700,000. The total value of all minerals mined in the world in 1872 amounted to $320,000,000, and that of coal to $610,000,000, or nearly double.

SPONTANEOUS COMBUSTION.

The chemical action known as spontaneous combustion is frequently the cause of fire, and great care should be taken in storing all materials likely to become the means of causing fire by this peculiarity. There can be no doubt that many fires, whose origin it has been difficult to explain, have arisen from this cause; and it is known that greasy or oily cotton, saw-dust, etc., if left long enough undisturbed, undergo a change, and finally ignite, setting fire to whatever inflammable material may be in their immediate vicinity. Even the decomposition of some kinds of coal in large bins, or in the holds of vessels,

has been known to be the cause of some very disastrous and lamentable fires.

Spontaneous ignition has been known to take place in the cotton wipings, or waste employed for wiping the oil, etc., from machinery; and there is little doubt that many fires, for which no apparent cause could be assigned, have thus originated. Even the putrefaction of vegetable matter has been known to occasion the development of so much heat as to sometimes cause its ignition. Galletly, who investigated the subject, found that cotton-waste soaked in boiled linseed-oil, and wrung out, if exposed to a temperature of 170°, set up oxidation so rapidly as to cause actual combustion in 105 minutes. It is important to note these facts, as they may be of great benefit to the owners and occupants of shops and factories.

TABLE

SHOWING THE TEMPERATURE AT WHICH DIFFERENT COMBUSTIBLE SUBSTANCES WILL IGNITE.

Substances.	Temp. of Ignition.	Substances.	Temp. of Ignition.
Phosphorus	140°	Picrate powder for torpedoes	570°
Bisulphide of carbon	300°	Picrate powder for muskets.	576°
Fulminating powder	374°	Charcoal, the most inflammable willow used for gunpowder	580°
Fulminate of mercury	392°	Charcoal, made by distilling wood at 500°	660°
Equal parts of chlorate of potash and sulphur	395°	Charcoal, made at 600°	700°
Sulphur	400°	Picrate powder for cannon.	716°
Gun-cotton	428°	Very dry wood, pine	800°
Nitro-glycerine	494°	Oak	900°
Rifle powder	550°	Steam at 240 lbs. pressure per square inch	403°
Gunpowder, coarse	563°		
Picrate of mercury, lead or iron	565°		

It will be seen from the above that steam, even at

this extraordinary high pressure, has a temperature not quite equal to one-half that required to ignite dry pine wood. The question will then naturally arise, are the steam-pipes used for heating buildings, having a temperature not generally more than from 250° to 300°, capable of firing wood. On this subject there seems to be a wide difference of opinion, for while it is held by some that such is the fact, it is claimed by others that no pressure of steam used for heating or manufacturing purposes, is of a sufficiently high temperature to produce such results. Still, it cannot be denied, that fires have frequently originated from steam-pipes, and at long distances from the boiler; and there can be no doubt that wood exposed to heat for a long time undergoes a process of semi-carbonization, and that the longer the process has been going on, the more readily the wood will ignite from any cause. How long it actually takes to effect this change in the wood, has never as yet been satisfactorily settled. Experiments are much needed to determine this important point.

When steam-pipes for heating purposes are properly put up, they may be regarded as safer than any mode of heating yet introduced into manufactories. The pipes should be (as most are in these days) supported on small iron hooks or brackets, removed at least one inch from any woodwork; and, when the main or conducting pipes pass through the floor or any wood partition, the hole should be larger than the diameter of the pipe, and a collar of tile, plaster of paris, asbestos, or some other good non-conducting substance inserted in it, through which the pipe should pass, leaving a space of at least half an inch around it. In the case of large pipes, the space should be proportionally large. The dust that accumulates on the top of steam-pipes should be frequently swept

off, and any dirt that may collect around, behind, or under them should be removed daily. The exercise of such precautions will render steam-heating apparatus perfectly safe.

The practice of covering main steam-pipes with wood is a very mischievous one, as, by enclosing steam-pipes in air-tight cases, the temperature may be indefinitely raised, until the point of inflammability is attained, so that if any part of the steam-pipes for heating purposes must be covered, some good non-conducting substance should invariably be used for that purpose. All steam-pipes running near floors or ceilings should be left exposed to the air, unless covered by some non-conductor, as, when heated bodies are exposed to the air, they lose portions of their heat by projection in right lines into space from all parts of their surface. This is called the radiation of heat.

STEAM.

Steam is the elastic fluid into which water is converted by the continued application of heat. It may be said to be the result of the combination of water with a certain amount of heat, and the expansive force of steam arises from the absence of cohesion in the particles of water.

The mechanical properties of vapor are similar to those of gases in general. The most important property to be considered, in the case of steam, is the elastic pressure. When a vapor or gas is contained in a close vessel, the inner surface of the vessel will sustain a pressure arising from the elasticity of the fluid. This pressure is produced by the mutual repulsion of the particles, which gives them a tendency to fly asunder, and causes the mass of the fluid to exert a force tending to burst any vessel within which it is confined. This pressure is uniformly diffused over

every part of the surface of the vessel in which such a fluid is contained: it is to this quality that all the mechanical power of steam is due.

Heat universally expands all matter within its influence, whether solid or fluid. But in a solid body it has the cohesion of the particles to overcome; and this so circumscribes its effect, that in cast-iron, for instance, a degree of temperature above the freezing-point sufficient to melt it causes an extension of only about one-eighth of an inch in a foot. With water, however, a temperature of 212°, or 180° above the freezing-point (which is far from a red heat), converts it into steam of 1700 times its original bulk or volume.

Steam cannot mix with air while its pressure exceeds that of the atmosphere; and it is this property, with that which makes the condition of a body dependent on its temperature, that explains the condensing property of steam. In a cylinder once filled with steam of a pressure of 15 pounds or more to the square inch, all air is excluded; now, as the existence of the steam depends on its temperature, by abstracting that temperature (which may be done by immersing the cylinder in cold water or cold air), the contained steam assumes the condition due to the reduced temperature, and this state will be water.

The latent or concealed heat of steam is one of the most noteworthy properties. The latent heat of steam, though showing no effect on the thermometer, may be as easily known as the sensible or perceptible heat. To show this property of steam by experiment, place an indefinite amount of water in a closed vessel, and let a pipe, proceeding from its upper part, communicate with another vessel, which should be open, and which, for convenience of illustration, should contain just $5\frac{1}{2}$ pounds of water at 32°, or just freezing. The pipe from the closed vessel must

reach nearly to the bottom of the open one. By boiling the water contained in the first vessel until steam enough has passed through the pipe to raise the water in the open vessel to the boiling-point (212° Fah.), we shall find the weight of the water contained by the latter to be 6½ pounds. Now, this addition of one pound to its weight has resulted solely from the admission of steam to it; and this pound of steam, therefore, retaining its own temperature of 212°, has raised 5½ pounds of water 180°, or an equivalent to 990°, and, including its own temperature, we have 1201°, which it must have possessed at first. The sum of the latent and sensible heat of steam is in all cases nearly constant, and does not vary much from 1200°.

The elasticity of steam increases with an increase in the temperature applied, but not in the same ratio. If steam is generated from water at a temperature which gives it the same pressure as the atmosphere, an additional temperature of 38° will give it the pressure of two atmospheres; a still further addition of 42° gives it the tension of four atmospheres; and with each successive addition of temperature of between 40° and 50° the pressure becomes doubled.

An established relation must exist between the temperature and elasticity of steam; in other words, water at 212° Fah. must be under the pressure of the steam naturally resulting from that temperature, and so at any other temperature. If this natural pressure on the surface of the water be removed without a corresponding reduction in the temperature, a violent ebullition of the water is the immediate result. Another result attending the formation of steam is, that, when an engine is in operation and working off a proper supply of steam, the water-level in the boiler artificially rises, showing by the gauge-cocks a greater supply than that which really exists.

As the pressure of steam is increased, the sensible heat is augmented, and the latent heat undergoes a corresponding diminution, and *vice versa.* The sum of the sensible and latent heat is, in fact, a constant quantity; the one being always increased at the expense of the other. It has been shown that to convert water at 32° of temperature, and under a pressure of 15 pounds per square inch, into steam, it was necessary first to give it 180° additional sensible heat, and afterwards 990° of latent heat, the total heat imparted to it being 1170°. Such, then, is the actual quantity of heat which must be imparted to ice-cold water to convert it into steam. The actual temperature to which water would be raised by the heat necessary to evaporate it, if its evaporation could be prevented by confining it in a close vessel, will be found by adding 32° to 1170°. It may, therefore, be stated that the heat necessary for the evaporation of ice-cold water is as much as would raise it to the temperature of 1202°, if its evaporation were prevented. If the temperature of red-hot iron be, as it is supposed, 800° or 900°, and if all bodies become incandescent at the same temperature, it follows that to evaporate water it is necessary to impart to it 400° more heat than would be sufficient to render it red hot, if its evaporation were prevented.

It has been asserted in some scientific works, that by mere mechanical compression steam will be converted into water. This is, however, an error; since steam, in whatever state it may exist, must possess at least 212° of heat; and as this quantity of heat is sufficient to maintain it in the form of vapor under whatever pressure it may be placed, it is clear that no compression or increase of pressure can diminish the actual quantity of heat contained in the steam, and it cannot, therefore, convert any portion of the steam into power.

Steam, by mechanical pressure, if forced into a diminished volume, will undergo an augmentation both of temperature and pressure, the increase of temperature being greater than the diminution of volume; in fact, any change of volume which it undergoes will be attended with the change of temperature and pressure indicated in the table on pages 338, 339. The steam, after its volume has been changed, will assume exactly the pressure and temperature which it would have in the same volume if it were immediately evolved from water.

Let us suppose a cubic inch of water converted into steam, under a pressure of 15 pounds per square inch, at the temperature of 212°. Then let its volume be reduced by compression in the proportion of 1700 to 930. When so reduced, its pressure will be found to have risen from 15 pounds per square inch to 29½ pounds per square inch; but this is exactly the condition as to pressure, temperature, and density which the steam would assume if it were immediately raised from water under the pressure of 29½ pounds per square inch. It appears, therefore, that in whatever manner, after evaporation, the density of steam be changed, whether by expansion or contraction, it will still remain the same as if it were immediately raised from water in its actual state. The circumstance which has given rise to the erroneous notion that mere mechanical compression will produce a condensation of steam, is that the vessel in which steam is contained must necessarily have the same temperature as the steam itself.

Water while passing into steam suffers a great enlargement of volume; steam, on the other hand, in being converted into water, undergoes a corresponding diminution of volume. It has been seen that a cubic inch of water, evaporated at the temperature of 212°, swells into 1700 cubic inches of steam. It follows, therefore, that if a

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closed vessel, containing 1700 cubic inches of steam, be exposed to cold sufficient to take from the steam all its latent heat, the steam will be reconverted into water, will shrink into its original dimensions, and will leave the remainder of the vessel a vacuum. This property of steam has supplied the means, in practical mechanics, of obtaining that amount of mechanical power which the properties of the atmosphere confer upon a vacuum.

The temperature and pressure of steam produced by immediate evaporation, when it has received no heat save that which it takes from the water, have a fixed relation one to the other. If this relation was known and expressed by a mathematical formula, the temperature might always be inferred from the pressure, and *vice versa*. But physical science has not yet supplied any principle by which such a formula can be deduced from any known properties of liquids. The same difficulty which attends the laying down of a general formula expressing the relation between the temperatures and pressures of steam, also attends the determination of one expressing the relation between the pressure and the augmented volume into which water expands by evaporation.

In the preceding observations, steam has been considered as receiving no heat except that which it takes from the water during the process of evaporation; the amount of which heat, as has been shown, is 1170° more than that contained in ice-cold water. But steam, after having been formed from water by evaporation, may, like all other material substances, receive an accession of heat from any external source, and its temperature may therefore be elevated.

If the steam to which such additional heat is imparted be so confined as to be incapable of enlarging its dimensions, the effect produced upon it by the increase of tem-

perature will be an increase of pressure. But if, on the other hand, it be confined under a given pressure, with power to enlarge its volume, and subject to the preservation of that pressure, as would be the case if it were contained in a cylinder under a movable piston loaded with a given pressure, then the effect of the augmented temperature will be, not an increase of pressure, but an increase of volume; and the increase of volume, in this latter case, will be in exactly the same proportion as the increase of pressure in the former case.

These effects of elevated temperature are common not only to the vapors of all liquids, but also to all permanent gases; but, what is much more remarkable, the numerical amount of the augmentation of pressure or volume produced by a given increase of temperature is the same for all vapors and gases. If the pressure which any gas or vapor would have (were it reduced to the temperature of melting ice) be expressed by 100,000, the pressure which it will receive for every degree of temperature by which it is raised will be expressed by 208⅓; or, what amounts to the same thing, the additional pressure produced by each degree of temperature will be the 480th part of its pressure at the temperature of melting ice.

Steam of atmospheric pressure occupies 1669 times the volume of the water from which it is raised, and as a cubic foot of water weighs 62.4 pounds, a cubic foot of steam of atmospheric pressure weighs about .038 pound. In order to exert a pressure by its mere dead weight of 14.7 pounds per square inch, such steam of uniform density would have to stand at a height of 10½ miles,—the velocity due to a fall from this height in 1888 feet per second,—and this, accordingly, is the velocity with which steam of atmospheric pressure enters a vacuum. And if the velocity of steam were inversely as its pressure, this would be the

velocity of steam of every pressure in moving into a vacuum, since, so far as generating effluent velocity is concerned, the mere elasticity of a gas is inoperative.

The effluent velocity of steam into the atmosphere or into steam of lower pressure, then, has to be carefully considered in the treatment of steam-engines. In the following table, the pressure given in pounds above the atmosphere is 0.3 pound less than the pressure employed in making the calculation:

Pressure above the Atmosphere.	Velocity of Escape per Second.	Pressure above the Atmosphere.	Velocity of Escape per Second.
Pounds.	Feet.	Pounds.	Feet.
1	540	50	1,736
2	698	60	1,777
3	814	70	1,810
4	905	80	1,835
5	981	90	1,857
10	1,232	100	1,875
20	1,476	110	1,889
30	1,601	120	1,900
40	1,681	130	1,909

To saturated steam, or steam as it rises from the water from which it is generated, these calculations of course only apply. Whatever may be the pressure per square inch common to different conditions of steam, the effluent velocity will be inversely as the square root of the specific gravity of steam. If the steam be superheated, its specific gravity for a given pressure will be diminished, and its velocity of escape into the air or into a vacuum will be increased. If, on the contrary, the steam carry with it any suspended moisture, its specific gravity for a given pressure will be increased and its velocity of escape diminished.

A very important question will probably arise in the mind of the reader as to the amount of work that a given

weight of steam is capable of performing. A pound of steam, having a pressure of 120 pounds above that of the atmosphere, is virtually a pound of water heated 1681 degrees above the absolute zero of a perfect gas thermometer, 1220° above Fahrenheit's zero, 1188 degrees above the freezing-point, or 1118° above the sensible temperature of steam of one pound absolute pressure per square inch, the lowest pressure at which a condensing-engine could be expected to work. Either of these total temperatures, multiplied by 772, will give the energy in foot-pounds theoretically due to the steam when worked down, say into water of the corresponding temperature.

But it must be remembered that, as a gas (to which steam in this case is necessarily compared) it would, upon the accepted law of expansion, only lose its elasticity at a temperature below the freezing-point. If we work down to 102°, the temperature of water from which steam of one pound total pressure would escape, we shall have an energy, for one pound weight of steam, of 863,096 foot-pounds; and if 10 pounds of steam be evaporated from 102° by one pound of coal, giving 8,630,960 foot-pounds per pound of coal, an engine working up to the full power of the steam would require but $\frac{1980000}{8630960} = 0.23$ pound, or less than *four ounces* of coal per indicated horse-power per hour, an hourly horse-power being $33{,}000 \times 60 = 1{,}980{,}000$ foot-pounds. To obtain such a result, the steam must in the very act of doing work be reduced to one pound of water at 102°. This, however, is quite a theoretical calculation, and nothing like it could, with our present knowledge, be attempted in practice; especially, as, in expanding, the steam is constantly losing heat and liquefying in the very act of doing work, and thus losing pressure apart from the loss due to the apparent enlargement of volume.

Steam which receives additional heat after its separation from the water from which it is evolved has been called *superheated steam*, to distinguish it from *common steam*, which is that usually employed in steam-engines. Superheated steam admits of losing a part of its heat without suffering partial condensation; but *common* steam is always partially condensed, if any portion of heat be withdrawn from it. But it must be remembered, that any additional arrangements for heating the steam can but complicate the machinery, and thus require increase of space, besides adding to the cost of the engine. But these objections are more serious in the case of the marine engine, the boilers of which are generally fed with sea-water strongly impregnated with various salts, and particularly with chloride of sodium. At the usual temperature of the steam used for working these engines, which is generally from 250° to 270°, the presence of this salt causes no inconvenience; but when the steam is superheated, chemical decomposition ensues; the chlorine thus set free attacks all the brass work of the engine with which it comes in contact, the valve and valve-seats are speedily destroyed, and the engine put out of order.

But there can be no doubt whatever that the use of superheated steam is more economical than that of ordinary saturated steam. In some of the scientific reports on this subject, it has been shown that there is a saving of from 20 to 25 per cent. in the fuel consumed. This fact has induced inventors to turn their attention to the task of devising some practical appliances for producing steam in this superheated condition.

Motion of Steam.—Steam, if unimpeded, moves with great velocity from one inclosure to another, under very slight differences of pressure. The laws which regulate this movement, though apparently of a simple character,

are not so easily reduced to exact formulæ as would seem desirable. All the rules, therefore, which are given, must be taken with due reserve and with important qualifications. The conditions of the free motion of steam will be exhibited as nearly as science has been able to estimate them.

These conditions are three: Steam may flow into a vacuum, or into the atmosphere, or into steam of less density. The conditions of its flow in all these cases are of course entirely different. In the middle case — that of its flow into the atmosphere — about 15 pounds of its total pressure go for nothing, being expended in overcoming the atmospheric resistance, and before the slightest motion of its own or impulse to any other body is possible. The law applicable to non-elastic fluids is the same as that which applies to gases and steam.

Volume and Weight of Steam.—Seventy-five cubic feet of steam at a pressure of 140 pounds per square inch weigh 26 pounds. Five cubic feet of steam at a pressure of 75 pounds per square inch weigh 1 pound. One cubic foot of steam at a pressure of 15 pounds per square inch weighs .038 pound.

Steam, at any given pressure, always stands at a certain temperature, which is termed the "temperature due to the pressure." Steam follows very nearly the same law to which all other gaseous bodies are subject in acquiring additional degrees of heat. This law is, briefly, as follows: That all gaseous bodies expand equally for equal additions of temperature; and that the progressive rate of expansion is equal for equal increments of temperature.

If two volumes of steam of the same weight be compared, we institute a comparison between their relative volumes; since, being of the same weight, they are produced from the same quantity of water. The relative

volume of steam being the absolute volume divided by the volume of water from which it was produced, the ratio of any two relative volumes of steam is the same as the ratio of their absolute volumes. So also with steam held in contact with the water in the boiler, — the pressure exhibited by the gauge corresponds to the same temperature in the boiler, and the temperature in the boiler will always give the same corresponding pressure of steam. Therefore, if we increase the temperature, we increase the pressure and density, and, of course, get the greatest pressure and density that steam can have at that temperature.

The table on page 338 shows that the saving of fuel is in proportion to the increase of pressure — the advantage of generating and using high-pressure steam is thereby made apparent. The table also shows that the last 10 pounds of additional pressure require only four degrees of heat to raise it; whereas, the first 10 pounds of pressure above the atmosphere require 29 additional degrees of heat to raise it — showing a difference of 25 degrees. It also shows that at 212° the total heat of steam is 1178.1°, which gives a difference of 966.1°. This heat, usually termed latent, is absorbed in performing the work of expanding the particles of water from the solid to the gaseous state. Now, suppose the water is evaporated at 60 pounds pressure, the steam will have a temperature of 307°, and a total heat of 1207°. If the feed has been introduced at 60°, it is evident that 1147° of heat have been imparted.

As the amount evaporated is inversely proportional to the quantity of heat required, we have $1147 \div 966 = 1.2$. Multiplying by this factor, the quantity evaporated at 60 pounds pressure from 60°, we obtain the amount that would be evaporated at 212° by the same quantity of fuel.

By the table (page 338) will be seen the comparatively

small increase of heat required to evaporate water at higher pressures. Suppose we take water evaporated at 45 pounds pressure from a feed temperature of 60°, then each pound of water will require 1202.7°— 60 = 1142.7° for its conversion into steam.

If we take the pressure at 100 pounds, we shall have 1216.5 — 60 = 1156.5° as the quantity required. The difference between these two total quantities is only 13.8°, and is so small as to be scarcely worth considering. Leaving out of account the loss due to the slight reduction of the conducting power of the material, the increased amount of heat required for the higher pressure will be only $\frac{1}{80}$ of the total heat required at 60 pounds. The economy of using steam of a high pressure is clearly manifest when, at the same time, advantage is taken of the facilities it offers for working expansively in the cylinder.

Theory has long since demonstrated the economical advantages to be derived from the use of high steam pressures combined with high grades of expansion in the cylinder. The practical difficulties that stood in the way having been gradually and successfully overcome, the result has been the marked changes from the 7 pound and 10 pound pressures, so common forty years ago, to the pressures of from 80 pounds to 100 pounds, at present employed; and the more general employment of the higher pressures will be demanded as the advantages of using steam expansively become more generally recognized.

ECONOMY OF WORKING STEAM EXPANSIVELY.

There are two modes of applying the power of steam to the working-cylinders of steam-engines, namely: One, allowing steam to flow from the boiler during the whole length of the stroke; and the other, cutting it off from

the boiler when the piston has travelled a determined distance — the great and paramount object of this last arrangement being a saving of fuel.

If steam be applied the full length of the stroke, the average pressure will be as the pressure per square inch upon the piston; but if the steam be cut off at half stroke,— suppose the pressure to be 65 pounds per inch when the pressure of the atmosphere is added,— there will be a mean equivalent, or average pressure, throughout the stroke of 55 pounds per square inch, being only 10 pounds less than the full pressure, or 16 per cent. of a loss in power, though half the former quantity of steam has only been used. This alone effects a saving of 34 per cent. in fuel, and shows the great benefit to be derived from expansion in one cylinder.

If this principle be true, and its truth is undeniable, it is quite evident that the greatest economy will result from extending to their full limit the cylinders of steam-engines, and making them of sufficient capacity for this purpose; though with the high-pressures, with which expansion is most available, they will require to be less than are usually made, to allow the engines to produce the maximum effect.

The expansive property of steam is strictly mechanical, and is a property common to all fluids — air, gas, etc. It simply consists in this — that vapor of a given elastic force will expand to certain limits, and during the process of expansion will act on opposing bodies with a force gradually decreasing, causing a diminution of elastic power in an inverse ratio of the increase of volume, until it has reached the limits of its power, or is counterbalanced by the resistance of a surrounding medium. Thus, steam of any given pressure, expanded to twice its origiual bulk, will exert only one-half its original power.

If a partial vacuum be formed on one side of a piston,

its motion will be continued until the density of the steam on the other side be as low as that of the uncondensed vapor on the vacuum side of the piston. It is clear that the power which may be obtained by thus impelling a piston will be the average between the highest and the lowest pressure upon the piston. It must also be understood that *it is a saving, and not a gain*, that thus results from expansion; a power being made available which was before lost, by using the steam up to its last impelling force, and not allowing it to escape until the whole of that available force has been expended.

This accounts for some engines using more fuel and steam than others, because the steam is not expanded to its utmost limit, in consequence of the steam not being cut off by the valve soon enough, or because the load on the engine is great, and requires the steam to be longer on the piston before it is cut off. If the load on the engine be such as to allow the steam to be cut off early, and to expand to its full available limits in the cylinder, then the most will have been made of it; the highest pressure in the boiler will have been used upon the piston and down to the lowest point.

Were atmospheric air compressed so as to exert a force of 20 pounds on the square inch, and were the supply to be continued throughout the stroke, an impulse would be given to the piston equal to 20 pounds to the square inch during the whole stroke; but if the air was allowed to expand, the impulse would only be as the average, or 10 pounds. It will be evident that, if in the former case the air was suffered to depart from the cylinder at the same elasticity as that at which it entered, we should lose the force which was necessary to compress it to its density; while, by expanding it to its limits, we apply every part of that force. The main-spring of a watch actuates its machinery

in this manner: an increasing effort is required to wind up the spring, and a decreasing impulse is given back to the machinery. But if, after the spring had partially uncoiled itself, it were then liberated, the force which wound it up to its last impelling point would be totally lost. So in the steam-engine; if the steam be allowed to escape from the cylinder before its force is expanded to the lowest available pressure, the loss will be in proportion to the amount of the pressure not made available.

A certain quantity of fuel is required to raise steam to a certain elasticity. If that steam be allowed, after having moved the piston, to escape into the atmosphere or condenser without having acted expansively, a portion of the fuel which was consumed to raise the steam up to that point of elasticity will have been lost. In one case, a given bulk of fuel would produce fifty; in the other case, it would produce fifty, added to all the intermediates down to the lowest expansive force. By this it will be apparent that the advantages arising from expansion increase with the density of the steam. In round numbers, 65 pounds of high-pressure steam will perform more than seven times the duty of 25 pounds of low-pressure steam; a fact greatly in favor of high-pressure steam and expansion.

Expansion is, perhaps, the most extraordinary property of steam. The merit of the discovery is due to HORNBLOWER, who, in 1781, obtained a patent for the invention. The principle of expanding the steam in the condensing engine is the same as in the non-condensing engine, with this exception,—the steam which exhausts into the atmosphere cannot expand below 15 pounds per square inch, because the exhaust is open to the pressure of the atmosphere in all cases. The resistance of the atmosphere (15 pounds) must be added to the pressure of steam above atmospheric pressure, when calculating the pressure of the expansion of steam upon the piston.

Example.—Steam at 20 pounds pressure above the atmosphere upon the piston, cut off at one-fourth the stroke, will be 8¾ pounds at the termination of the stroke, as shown by the following calculation: 20 pounds added to 15 pounds, the pressure of the atmosphere, equal 35 pounds. This divided by four gives the quotient, 8¾ pounds. Thus, 8¾ pounds is the pressure at the termination of the stroke, or 6¼ pounds below atmospheric pressure.

The tables on pages 336 and 337 show the average pressure of steam upon the piston when cut off at any portion of the stroke, beginning at 25 pounds and advancing in 5 pounds up to 135 pounds per square inch, thereby enabling the engineer to determine, at any given pressure, the amount of expansion requisite to obtain the full power to be obtained, and the saving thereby to be effected. In all cases the pressure of the atmosphere must be added to the pressure of the steam above the atmosphere, when reference is made to the table for the average throughout the stroke.

Example.—45 pounds of steam above atmosphere upon the piston of a high-pressure engine, cut off at one-fourth of the length of the stroke. The average pressure throughout will be, allowing one pound for friction and back pressure to force out the steam in the cylinder, 19¾ pounds. Thus: 45 pounds of steam cut off at one-fourth the stroke, with 15 pounds added, make 60 pounds. Look for 60 on the top line of the table and ¼ on the side. Trace that ¼ to the figures under 60, and the average will be found to be 35¾ pounds. Take 16 pounds from 35¾ pounds for atmospheric pressure and friction, and there remain 19¾ pounds, the available average pressure on the piston.

Example.—30 pounds cut off at one-third. Add 15=45. The average in the table will be 31½; deduct 16 pounds, and there remain 15½ pounds, the available average pressure upon the piston.

Another Example.—15 pounds cut off at half-stroke. Add 15 = 30. The average in the table will be 25¼. Deduct 16 pounds, and 9¼ pounds remain, the available pressure. In these examples the steam in the cylinder has expanded to atmospheric pressure. In proportion to the pressure of the steam, the cut-off will have to be varied, if the steam is to be expanded to its full limit in the cylinder of a non-condensing engine; that is, down to 15 pounds, or equal to the pressure of the atmosphere.

Rule for ascertaining the Amount of Benefit to be derived from working Steam expansively.—Divide the length of the stroke by the length of space into which steam is admitted; find in the annexed table the hyperbolic logarithm nearest to that of the quotient, to which add one. The sum is the ratio of gain.

TABLE

OF HYPERBOLIC LOGARITHMS TO BE USED IN CONNECTION WITH THE ABOVE RULE.

No.	Logarithm.	No.	Logarithm.	No.	Logarithm.
1.25	.22314	5.	1.60943	9.	2.19722
1.5	.40546	5.25	1.65822	9.5	2.25129
1.75	.55961	5.5	1.70474	10.	2.30258
2.	.69314	5.75	1.74919	11.	2.39789
2.25	.81093	6.	1.79175	12.	2.48490
2.5	.91629	6.25	1.83258	13.	2.56494
2.75	1.01160	6.5	1.87180	14.	2.63905
3.	1.09861	6.75	1.90954	15.	2.70805
3.25	1.17865	7.	1.94591	16.	2.77258
3.5	1.25276	7.25	1.98100	17.	2.83321
3.75	1.32175	7.5	2.01490	18.	2.89037
4.	1.38629	7.75	2.04769	19.	2.94443
4.25	1.44691	8.	2.07944	20.	2.99573
4.5	1.50507	8.5	2.14006	21.	3.04452
4.75	1.55814			22.	3.09104

Rule for finding the Mean or Average Pressure in a Cylinder.—Divide the length of the stroke (including the

clearance at one end of the cylinder) by the distance (including the clearance at one end) that the steam follows the piston before being cut off; the quotient will express the relative expansion the steam undergoes. Then find in the following table, in the expansion column, the number corresponding to this; take the multiplier opposite to it, and multiply the full pressure of the steam per square inch, as it enters the cylinder, by it.

TABLE

OF MULTIPLIERS BY WHICH TO FIND THE MEAN PRESSURE OF STEAM AT VARIOUS POINTS OF CUT-OFF.

Expansion.	Multiplier.	Expansion.	Multiplier.	Expansion.	Multiplier.
1.0	1.000	3.4	.654	5.8	.479
1.1	.995	3.5	.644	5.9	.474
1.2	.985	3.6	.634	6.	.470
1.3	.971	3.7	.624	6.1	.466
1.4	.955	3.8	.615	6.2	.462
1.5	.937	3.9	.605	6.3	.458
1.6	.919	4.	.597	6.4	.454
1.7	.900	4.1	.588	6.5	.450
1.8	.882	4.2	.580	6.6	.446
1.9	.864	4.3	.572	6.7	.442
2.	.847	4.4	.564	6.8	.438
2.1	.830	4.5	.556	6.9	.434
2.2	.813	4.6	.549	7.	.430
2.3	.797	4.7	.542	7.1	.427
2.4	.781	4.8	.535	7.2	.423
2.5	.766	4.9	.528	7.3	.420
2.6	.752	5.	.522	7.4	.417
2.7	.738	5.1	.516	7.5	.414
2.8	.725	5.2	.510	7.6	.411
2.9	.712	5.3	.504	7.7	.408
3.	.700	5.4	.499	7.8	.405
3.1	.688	5.5	.494	7.9	.402
3.2	.676	5.6	.489	8.	.399
3.3	.665	5.7	.484		

TABLE

SHOWING THE AVERAGE PRESSURE OF THE STEAM UPON THE PISTON THROUGHOUT THE STROKE, WHEN CUT OFF IN THE CYLINDER FROM $\frac{1}{3}$ TO $\frac{7}{11}$, COMMENCING WITH 25 POUNDS AND ADVANCING IN 5 POUNDS UP TO 75 POUNDS PRESSURE.

Steam cut off in the Cylinder.	Pressure in Pounds at the Commencement of the Stroke.										
	25	30	35	40	45	50	55	60	65	70	75
	Average Pressure in Pounds upon the Piston.										
1/3	17½	21	24½	28	31½	35	38½	42	45½	49	52½
2/3	23½	28¼	32¾	37½	42	46¾	51½	56¼	61	65½	70¼
1/4	15	17¾	20¾	23¾	26¾	29¾	32¾	35¾	38¾	41¾	44¾
1/2	21	25¼	29½	33¾	38	42¼	46½	50¾	55	59¼	63½
3/4	24	81¾	33½	38½	43¼	48¼	53	57¾	62½	67½	72¼
1/5	13	15½	18¼	20¾	23½	26	28½	31¼	34	36½	39
2/5	19	23	26¾	30½	39½	38¼	42	46	49¾	53½	57½
3/5	22½	26	31½	39¼	40¾	45¼	49¾	54¼	58¾	63¼	67¾
4/5	23¾	29¼	34¼	39	44	49	53¾	58½	63½	68½	73¾
1/6	11½	14	16¼	18½	20¾	23¼	25½	27¾	30¼	32½	34¾
5/6	24½	29½	34½	39½	44¼	49¼	54	59	64	69	73¾
1/7	10½	12½	14¾	16¾	18¾	24	23¼	25¼	27¼	29½	31½
2/7	16	19¼	22½	25¾	28¾	32	35¼	38½	41¾	45	48¼
3/7	19¾	23¾	27¾	31½	35½	39½	43	47½	51½	55¼	59¼
4/7	22¼	26¾	31¼	35½	40	44½	49½	53½	57¾	62½	66¾
5/7	23¾	28½	33½	38¼	42¾	47¾	52½	57¼	62	66¾	71½
6/7	24¾	29½	34½	39½	44½	49½	54¼	59¼	63¾	69¼	74¼
1/8	9½	11½	13½	15¼	17¼	19¼	21¼	23	25	27	28¾
3/8	18½	22¼	26	29¾	33½	37	40¾	44½	48¼	52	55¾
5/8	22¾	27½	32	36¾	41¼	45½	50½	55¼	59¾	64¼	68¾
7/8	24¾	29¾	34¾	39½	44½	49½	54½	59½	64½	69¼	74¼
1/9	8¾	10½	12¼	14¼	15¾	17¾	19½	21¼	23	24¾	26½
2/9	13¾	16½	19¼	22¼	25	27¾	30½	33¼	36	38¾	41¾
4/9	20	24	28	32	36	40¼	44¼	48¼	52¼	56¼	60¼
5/9	22	26¼	30¾	35¼	39½	44	48½	52¾	56½	61¾	66
7/9	24¼	29	34	38¾	43¾	48½	53½	58¼	63¼	68	72¾
8/9	24¾	29¾	34¾	39¾	44½	49½	54½	59½	64½	69½	74½
1/11	7¾	9¼	10¾	12¼	13¾	15¼	16¾	18½	20	21½	23
2/11	12¼	14¾	17¼	19½	22	24½	27	29½	31¾	34¼	36¾
3/11	15½	18¾	21¾	25	28	31¼	34¼	37½	40¾	43¾	47
4/11	18¼	21¾	25½	29¼	32¾	36½	40¼	43¾	47½	51	54¾
5/11	20¼	24¼	28¼	32½	36½	40½	44½	48¾	52¾	56¾	60¾
6/11	21¾	26¼	30½	35	39¼	43¾	48	52¼	56¾	61¼	65½
7/11	23	27½	32¼	36¾	41½	46	50¾	55¼	60	64½	69¼

TABLE

SHOWING THE AVERAGE PRESSURE OF STEAM UPON THE PISTON THROUGHOUT THE STROKE, WHEN CUT OFF IN THE CYLINDER FROM ⅓ TO 7/9, COMMENCING WITH 80 POUNDS AND ADVANCING IN 5 POUNDS UP TO 130 POUNDS PRESSURE.

Steam cut off in the Cylinder.	Pressure in Pounds at the Commencement of the Stroke.										
	80	85	90	95	100	105	110	115	120	125	130
	Average Pressure in Pounds upon the Piston.										
1/3	56	59½	63	66½	70	73	77½	80½	84	87½	91
2/3	75	79½	84½	89	93¾	98¼	103	107¾	112½	117	121¾
1/4	47¾	50¾	53¾	56¾	59¾	62¾	95½	68½	71½	74½	77½
1/2	67¾	72	76¼	80½	84¾	89	73¼	97¼	101½	105¾	110
3/4	77¼	82	87	91¾	96½	101¼	106¼	111	115¾	120¾	125½
1/5	41¾	44¼	47	49½	52¼	54¾	57¼	60	62½	65¼	67¾
2/5	61¼	65	69	72¾	76½	80¼	84¼	88	91¾	95¾	99½
3/5	72½	77	81½	86	90½	95¼	99½	104¼	108¾	113¼	117¾
4/5	78¼	83	88	92¾	97¾	102¾	107½	112½	117½	122¼	127¼
1/6	37¼	39½	41¾	44¼	46½	48¾	51¼	53½	55¾	58	60¾
5/6	78¾	83¾	88¾	93½	98½	103½	108¼	113¼	118¼	123½	128
1/7	33½	35¾	37¾	40	42	44	46¼	48¼	50½	52½	54½
2/7	51½	54½	57¾	61	64¼	67½	70¾	74	77¼	80½	83½
3/7	63¼	67¼	71¼	75¼	79	83	87	91	94¾	98¾	102¼
4/7	71¼	75¾	80	84½	89	93½	98	102½	106¾	111½	115¾
5/7	76¼	81	85¾	90¾	95½	100¼	105	109¾	114½	119¼	124
6/7	79	84	89	93¾	98¾	103¾	108¾	113¾	118¾	123½	128½
1/8	30¾	32¾	34½	36½	38½	40½	42¾	44½	46¼	48	50
3/8	59½	63	66¾	70½	74¼	78	81¾	85½	89	92¾	96½
5/8	73½	78	82½	87¼	91¾	96½	101	105½	110¼	114¾	119½
7/8	79¼	84¼	89¼	94¼	99	104	109	114	119	124	128¾
1/9	28¼	30¼	31¾	33¾	35½	37¼	39	40¾	42½	44¼	46
2/9	44½	47¼	55	57¾	55½	58¼	61	63¾	66¾	69½	72¼
4/9	64¼	68¼	72¼	76¼	80½	84½	88½	92½	96½	100½	104½
5/9	70½	74¾	79¼	83¾	88	92½	97	101¼	105¾	110¼	114½
7/9	77¾	82¾	87½	92¼	97¼	102	107	111¾	116¾	121½	126½

TABLE

SHOWING THE TEMPERATURE OF STEAM AT DIFFERENT PRESSURES, FROM 1 LB. PER SQUARE INCH TO 240 LBS., AND THE QUANTITY OF STEAM PRODUCED FROM A CUBIC-INCH OF WATER, ACCORDING TO PRESSURE.

It is necessary to add the pressure of the atmosphere, 15 pounds, to the pressure on the steam-gauge, to correspond with the table.

Total Pressure of Steam in lbs. per Square Inch.	Correspond-ing Temper-ature of Steam to Pressure.	Cubic Inches of Steam from a Cubic Inch of Water according to Pressure.	Total Pressure of Steam in lbs. per Square Inch.	Correspond-ing Temper-ature of Steam to Pressure.	Cubic Ins. St'm from a Cubic In. of Water according to Press.
1	102.9	20868	35	260.9	767
2	126.1	10874	36	262.6	748
3	141.0	7437	37	264.3	729
4	152.3	5685	38	265.9	712
5	161.4	4617	39	267.5	695
6	169.2	3897	40	269.1	679
7	175.9	3376	41	270.6	664
8	182.0	2983	42	272.1	649
9	187.4	2674	43	273.6	635
10	192.4	2426	44	275.0	622
11	197.0	2221	45	276.4	610
12	201.3	2050	46	277.8	598
13	205.3	1904	47	279.2	586
14	209.1	1778	48	280.5	575
15 Press. of Atmsphr.	212.8	1669	49	281.9	564
16	216 3	1573	50	283.2	554
17	219.6	1488	51	284.4	544
18	222 7	1411	52	285.7	534
19	225.6	1343	53	286.9	525
20	228.5	1281	54	288.1	516
21	231.2	1225	55	289.3	508
22	233.8	1174	56	290.5	500
23	236.3	1127	57	291.7	492
24	238.7	1084	58	292.9	484
25	241.0	1044	59	294.2	477
26	243.3	1007	60	295 6	470
27	245.5	973	61	296.9	463
28	247.6	941	62	298.1	456
29	249.6	911	63	299.2	449
30	251.6	883	64	300.3	443
31	253 6	857	65	301.3	437
32	255.5	833	66	302.4	431
33	257.3	810	67	303.4	425
34	259.1	788	68	304.4	419

TABLE—(*Continued.*)

Total Pressure of Steam in lbs. per Square Inch.	Corresponding Temperature of Steam to Pressure.	Cubic Ins. of Steam from a Cubic In. of Water according to Pressure.	Total Pressure of Steam in lbs. per Square Inch.	Corresponding Temperature of Steam to Pressure.	Cubic Ins. of Steam from a Cubic In. of Water according to Pressure.
69	305.4	414	92	325.9	319
70	306.4	408	93	326.7	316
71	307.4	403	94	327.5	313
72	308.4	398	95	328.2	310
73	309.3	393	96	329.0	307
74	310.3	388	97	329.8	304
75	311.2	383	98	330.5	301
76	312.2	379	99	331.3	298
77	313.1	374	100	332.0	295
78	314.0	370	110	339.2	271
79	314.9	366	120	345.8	251
80	315.8	362	130	352.1	233
81	316.7	358	140	357.9	218
82	317.6	354	150	363.4	205
83	318.4	350	160	368.7	193
84	319.3	346	170	373.6	183
85	320.1	342	180	378.4	174
86	321.0	339	190	382.9	166
87	321.8	335	200	387.3	158
88	322.6	332	210	391.5	151
89	323.5	328	220	395.5	145
90	324.3	325	230	399.4	140
91	325.1	322	240	403.1	134

EXPLANATION OF THE FOLLOWING TABLE.

The first column gives the absolute pressure of the steam in inches of mercury, or the height to which the pressure would raise a column of mercury in a tube, provided the opposing pressure of the atmosphere were removed.

The second column gives the absolute pressure in pounds per square inch under the same circumstances.

The third column, it will be observed, is headed "Pressure above Atmosphere." By this is meant the apparent pressure of the steam as indicated by a steam-gauge.

The fourth column shows the temperature in degrees of Fahrenheit's scale.

The fifth column shows the increase of volume which the water assumes in the act of changing into steam.

The sixth column shows the velocity with which steam, at the given pressures, escapes through an orifice into the atmosphere, as, for example, through the safety-valve of a steam-boiler.

TABLE

OF THE ELASTIC FORCE, TEMPERATURE, AND VOLUME OF STEAM FROM A TEMPERATURE OF 32° TO 457° FAH., AND FROM A PRESSURE OF 0.2 TO 900 INCHES OF MERCURY.

ELASTIC FORCE IN		Press. above Atmosphere	Temper-ature.	Volume.	Velocity of Escape.
Inches of Mercury.	Pounds per Square Inch.				
.200	.098		32°	187407	
.221	.108		35	170267	
.263	.129		40	144529	
.316	.155		45	121483	
.375	.184		50	103350	
.443	.217		55	88388	
.524	.257		60	75421	
.616	.302		65	64762	
.721	.353		70	55862	
.851	.417		75	47771	
1.000	.49		80	41031	
1.17	.573		85	35393	
1.36	.666		90	30425	
1.58	.774		95	26686	
1.86	.911		100	22873	
2.04	1.000		103	20958	
2.18	1.068		105	19693	
2.53	1.24		110	16667	
2.92	1.431		115	14942	
3.33	1.632		120	13215	
3.79	1.857		125	11723	
4.34	2.129		130	10328	
5.00	2.45		135	9036	
5.74	2.813		140	7938	
6.53	3.100		145	7040	
7.42	3.636		150	6243	
8.40	4.116		155	5559	
9.46	4.635		160	4976	
10.68	5.23		165	4443	
12.13	5.94		170	3943	
13.62	6.67		175	3538	
15.15	7.42		180	3208	
17.00	8.33		185	2879	
19.00	9.31		190	2595	
21.22	10.40		195	2342	
23.64	11.58		200	2118	
26.13	12.80		205	1932	
28.84	14.13		210	1763	

TABLE—(*Continued.*)

ELASTIC FORCE IN		Press. above Atmosphere	Temper-ature.	Volume.	Velocity of Escape.
Inches of Mercury.	Pounds per Square Inch.				
29.41	14.41		211. °	1730	
30.00	14.70	0.	212.	1700	
30.60	15.00		212.8	1669	
31.62	15.50	0.8	214.5	1618	
32.64	16.00	1.3	216.3	1573	
33.66	16.50		218.	1530	
34.68	17.00	2.3	219.6	1488	
35.70	17.50		221.2	1440	
36.72	18.00	3.3	222.7	1411	
37.74	18.50		224.2	1377	874
38.76	19.00	4.3	225.6	1343	
39.78	19.50		227.1	1312	
40.80	20.00	5 3	228.5	1281	
41.82	20.50		229.9	1253	
42.84	21.00	6.3	231.2	1225	
43.86	21.50		232.5	1199	
44.88	22.00	7.3	233.8	1174	1135
45.90	22.50		235.1	1150	
46.92	23.00	8.3	236.3	1127	
47 94	23.50		237.5	1105	
48.96	24.00	9.3	238.7	1084	
49.98	24.50		239.9	1064	
51.00	25.00	10.3	241.	1044	
53.04	26.00	11.3	243.3	1007	1295
55.08	27.	12.3	245.5	973	
57.12	28.	13.3	247.6	941	
59.16	29.	14.3	249.6	911	1407
61.20	30.	15.3	251.6	883	
63.24	31.	16.3	253.6	857	
65.28	32.	17.3	255.5	833	
67.32	33.	18.3	257.3	810	1491
63 96	34.	19.3	259.1	788	
71.40	35.	20.3	260.9	767	
73.44	36.	21.3	262.6	748	
75.48	37.	22.3	264.3	729	1550
77.52	38.	23.3	265.9	712	
79.56	39.	24.3	267.5	695	
81.60	40.	25.3	269.1	679	1600
83.64	41.	26.3	270.6	664	
85.68	42.	27.3	272.1	649	
87.72	43.	28.3	273.6	635	

TABLE—(*Continued.*)

ELASTIC FORCE IN		Press. above Atmosphere	Temperature.	Volume.	Velocity of Escape.
Inches of Mercury.	Pounds per Square Inch.				
89.76	44.	29.3	275. °	622	1652
91.80	45.	30 3	276.4	610	
93.84	46.	31.3	277.8	598	
95.88	47.	32.3	279.2	586	
97.92	48.	33.3	280.5	575	1690
99.96	49.	34.3	281.9	564	
102.00	50.	35 3	283.2	554	
104.04	51.	36.3	284.4	544	1720
106.08	52.	37 3	285.7	534	
108.12	53.	38.3	286.9	525	.
110.16	54.	39.3	288.1	516	
112.20	55.	40.3	289.3	508	1750
114.24	56.	41.3	290.5	500	
116.28	57.	42.3	291.7	492	
118.32	58.	43.3	292.9	484	1774
120.36	59.	44.3	294.2	477	
122.40	60.	45.3	295.6	470	
124.44	61.	46.3	296.9	463	
126.48	62.	47.3	298.1	456	
128.52	63.	48.3	299.2	449	
130.66	64.	49.3	300.3	443	
132.60	65.	50.3	301.3	437	
134.64	66.	51 3	302.4	431	1816
136.68	67.	52.3	303.4	425	
138.72	68.	53.3	304.4	419	
140.76	69.	54.3	305.4	414	
142.80	70.	55.3	306.4	408	
144.84	71.	56.3	307.4	403	
146.88	72.	57.3	308.4	398	
148.92	73.	58.3	309.3	393	1850
150.96	74.	59.3	310.3	388	
153.02	75.	60 3	311.2	383	
155.06	76.	61.3	312.2	379	
157.10	77.	62.3	313.1	374	
159.14	78.	63.3	314.	370	
161.18	79.	64.3	314.9	366	
163.22	80.	65.3	315.8	362	
165.26	81.	66.3	316.7	358	
167.30	82.	67.3	317.7	354	
169.34	83.	68.3	318.4	350	
171.38	84.	69.3	319.3	346	

TABLE—(*Continued.*)

ELASTIC FORCE IN		Press. above Atmosphere	Temper-ature.	Volume.	Velocity of Escape.
Inches of Mercury.	Pounds per Square Inch.				
173.42	85.	70.3	320.1°	342	
183.62	90.	75.3	324.3	325	1904
193.82	95.	80 3	328.2	310	
203.99	100.	85.3	332.	295	
214.19	105.	90.3	335.8	282	1950
224.39	110.	95.3	339.2	271	
234.59	115.	100.3	342.7	259	
244.79	120.	105 3	345.8	251	1980
254.99	125.	1 10.3	349.1	240	
265.19	130.	1 15.3	352.1	233	
275.39	135.	1 20.3	355.	224	2006
285.59	140.	125.3	357.9	218	
295.79	145.	130.3	360.6	210	
306.	150.	135.3	363.4	205	2029
316.19	155.	140 3	366.	198	
326.29	160.	145.3	368.7	193	
336.59	165.	150.3	371.1	187	
346.79	170.	155.3	373.6	183	
357.	175.	160.3	376.	178	
367.2	180.	165.3	378.4	174	
377.1	185.	170.3	380.6	169	2074
387.6	190.	175.3	382.9	166	
397.8	195.	180 3	384.1	161	
408.	200.	185.3	387 3	158	
448.8	220.	205 3	392.		2109
524.28	257.	242.3	406.		2136
599.76	294.	279.3	418.		2159
848.68	367.	352.3	429.		2196
889.64	441.	426 3	457.		2226

TABLE

SHOWING THE TEMPERATURE AND WEIGHT OF STEAM AT DIFFERENT PRESSURES FROM 1 POUND PER SQUARE INCH TO 300 POUNDS, AND THE QUANTITY OF STEAM PRODUCED FROM 1 CUBIC INCH OF WATER, ACCORDING TO PRESSURE.

Total pressure per square inch measured from a vacuum.	Pressure above atmosphere.	Sensible temperature in Fahrenheit degrees.	Total heat in degrees from zero of Fahrenheit.	Weight of one cubic foot of steam.	Relative volume of steam compared with water from which it was raised.
1	......	102.1	1144.5	.0030	20582
2	......	126.3	1151.7	.0058	10721
3	......	141.6	1156.6	.0085	7322
4	......	153.1	1160.1	.0112	5583
5	......	162.3	1162.9	.0138	4527
6	......	170.2	1165.3	.0163	3813
7	......	176.9	1167.3	.0189	3298
8	......	182.9	1169.2	.0214	2909
9	......	188.3	1170.8	.0239	2604
10	......	193.3	1172.3	.0264	2358
11	......	197.8	1173.7	.0289	2157
12	......	202.0	1175.0	.0314	1986
13	......	205.9	1176.2	.0338	1842
14	......	209.6	1177.3	.0362	1720
14.7	0	212.0	1178.1	.0380	1642
15	.3	213.1	1178.4	.0387	1610
16	1.3	216.3	1179.4	.0411	1515
17	2.3	219.6	1180.3	.0435	1431
18	3.3	222.4	1181.2	.0459	1357
19	4.3	225.3	1182.1	.0483	1290
20	5.3	228.0	1182.9	.0507	1229
21	6.3	230.6	1183.7	.0531	1174
22	7.3	233.1	1184.5	.0555	1123
23	8.3	235.5	1185.2	.0580	1075
24	9.3	237.8	1185.9	.0601	1036
25	10.3	240.1	1186.6	.0625	996
26	11.3	242.3	1187.3	.0650	958
27	12.3	244.4	1187.8	.0673	926
28	13.3	246.4	1188.4	.0696	895
29	14.3	248.4	1189.1	.0719	866
30	15.3	250.4	1189.8	.0743	838
31	16.3	252.2	1190.4	.0766	813

TABLE—(*Continued*).

Total pressure per square inch measured from a vacuum.	Pressure above atmosphere.	Sensible temperature in Fahrenheit degrees.	Total heat in degrees from zero of Fahrenheit.	Weight of one cubic foot of steam.	Relative volume of steam compared with water from which it was raised.
32	17.3	254.1	1190.9	.0789	789
33	18.3	255.9	1191.5	.0812	767
34	19.3	257.6	1192.0	.0835	746
35	20.3	259.3	1192.5	.0858	726
36	21.3	260.9	1193.0	.0881	707
37	22.3	262.6	1193.5	.0905	688
38	23.3	264.2	1194.0	.0929	671
39	24.3	265.8	1194.5	.0952	655
40	25.3	267.3	1194.9	.0974	640
41	26.3	268.7	1195.4	.0996	625
42	27.3	270.2	1195.8	.1020	611
43	28.3	271.6	1196.2	.1042	598
44	29.3	273.0	1196.6	.1065	595
45	30.3	274.4	1197.1	.1089	572
46	31.3	275.8	1197.5	.1111	561
47	32.3	277.1	1197.9	.1133	550
48	33.3	278.4	1198.3	.1156	539
49	34.3	279.7	1198.7	.1179	529
50	35.3	281.0	1199.1	.1202	518
51	36.3	282.3	1199.5	.1224	509
52	37.3	283.5	1199.9	.1246	500
53	38.3	284.7	1200.3	.1269	491
54	39.3	285.9	1200.6	.1291	482
55	40.3	287.1	1201.0	.1314	474
56	41.3	288.2	1201.3	.1336	466
57	42.3	289.3	1201.7	.1364	458
58	43.3	290.4	1202.0	.1380	451
59	44.3	291.6	1202.4	.1403	444
60	45.3	292.7	1202.7	.1425	437
61	46.3	293.8	1203.1	.1447	430
62	47.3	294.8	1203.4	.1469	424
63	48.3	295.9	1203.7	.1493	417
64	49.3	296.9	1204.0	.1516	411
65	50.3	298.0	1204.3	.1538	405
66	51.3	299.0	1204.6	.1560	399
67	52.3	300.0	1204.9	.1583	393
68	53.3	300.9	1205.2	.1605	388
69	54.3	301.9	1205.5	.1627	383

TABLE—(*Continued*).

Total pressure per square inch measured from a vacuum.	Pressure above atmosphere.	Sensible temperature in Fahrenheit degrees.	Total heat in degrees from zero of Fahrenheit.	Weight of one cubic foot of steam.	Relative volume of steam compared with water from which it was raised.
70	55.3	302.9	1205.8	.1648	378
71	56.3	303.9	1206.1	.1670	373
72	57.3	304.8	1206.3	.1692	368
73	58.3	305.7	1206.6	.1714	363
74	59.3	306.6	1206.9	.1736	359
75	60.3	307.5	1207.2	.1759	353
76	61.3	308.4	1207.4	.1782	349
77	62.3	309.3	1207.7	.1804	345
78	63.3	310.2	1208.0	.1826	341
79	64.3	311.1	1208.3	.1848	337
80	65.3	312.0	1208.5	.1869	333
81	66.3	312.8	1208.8	.1891	329
82	67.3	313.6	1209.1	.1913	325
83	68.3	314.5	1209.4	.1935	321
84	69.3	315.3	1209.6	.1957	318
85	70.3	316.1	1209.9	.1980	314
86	71.3	316.9	1210.1	.2002	311
87	72.3	317.8	1210.4	.2024	308
88	73.3	318.6	1210.6	.2044	305
89	74.3	319.4	1210.9	.2067	301
90	75.3	320.2	1211.1	.2089	298
91	76.3	321.0	1211.3	.2111	295
92	77.3	321.7	1211.5	.2133	292
93	78.3	322.5	1211.8	.2155	289
94	79.3	323.3	1212.0	.2176	286
95	80.3	324.1	1212.3	.2198	283
96	81.3	324.8	1212.5	.2219	281
97	82.3	325.6	1212.8	.2241	278
98	83.3	326.3	1213.0	.2263	275
99	84.3	327.1	1213.2	.2285	272
100	85.3	327.9	1213.4	.2307	270
101	86.3	328.5	1213.6	.2329	267
102	87.3	329.1	1213.8	.2351	265
103	88.3	329.9	1214.0	.2373	262
104	89.3	330.6	1214.2	.2393	260
105	90.3	331.3	1214.4	.2414	257
106	91.3	331.9	1214.6	.2435	255
107	92.3	332.6	1214.8	.2456	253

TABLE—(*Continued*).

Total pressure per square inch measured from a vacuum.	Pressure above atmosphere.	Sensible temperature in Fahrenheit degrees.	Total heat in degrees from zero of Fahrenheit.	Weight of one cubic foot of steam.	Relative volume of steam compared with water from which it was raised.
108	93.3	333.3	1215.0	.2477	251
109	94.3	334.0	1215.3	.2499	249
110	95.3	334.6	1215.5	.2521	247
111	96.3	335.3	1215.7	.2543	245
112	97.3	336.0	1215.9	.2564	243
113	98.3	336.7	1216.1	.2586	241
114	99.3	337.4	1216.3	.2607	239
115	100.3	338.0	1216.5	.2628	237
116	101.3	338.6	1216.7	.2649	235
117	102.3	339.3	1216.9	.2674	233
118	103.3	339.9	1217.1	.2696	231
119	104.3	340.5	1217.3	.2738	229
120	105.3	341.1	1217.4	.2759	227
121	106.3	341.8	1217.6	.2780	225
122	107.3	342.4	1217.8	.2801	224
123	108.3	343.0	1218.0	.2822	222
124	109.3	343.6	1218.2	.2845	221
125	110.3	344.2	1218.4	.2867	219
126	111.3	344.8	1218.6	.2889	217
127	112.3	345.4	1218.8	.2911	215
128	113.3	346.0	1218.9	.2933	214
129	114.3	346.6	1219.1	.2955	212
130	115.3	347.2	1219.3	.2977	211
131	116.3	347.8	1219.5	.2999	209
132	117.3	348.3	1219.6	.3020	208
133	118.3	348.9	1219.8	.3040	206
134	119.3	349.5	1220.0	.3060	205
135	120.3	350.1	1220.2	.3080	203
136	121.3	350.6	1220.3	.3101	202
137	122.3	351.2	1220.5	.3121	200
138	123.3	351.8	1220.7	.3142	199
139	124.3	352.4	1220.9	.3162	198
140	125.3	352.9	1221.0	.3184	197
141	126.3	353.5	1221.2	.3206	195
142	127.3	354.0	1221.4	.3228	194
143	128.3	354.5	1221.6	.3258	193
144	129.3	355.0	1221.7	.3273	192
145	130.3	355.6	1221.9	.3294	190

TABLE—(*Concluded*).

Total pressure per square inch measured from a vacuum.	Pressure above atmosphere.	Sensible temperature in Fahrenheit degrees.	Total heat in degrees from zero of Fahrenheit.	Weight of one cubic foot of steam.	Relative volume of steam compared with water from which it was raised.
146	131.3	356.1	1222.0	.3315	189
147	132.3	356.7	1222.2	.3336	188
148	133.3	357.2	1222.3	.3357	187
149	134.3	357.8	1222.5	.3377	186
150	135.3	358.3	1222.7	.3397	184
155	140.3	361.0	1223.5	.3500	179
160	145.3	363.4	1224.2	.3607	174
165	150.3	366.0	1224.9	.3714	169
170	155.3	368.2	1225.7	.3821	164
175	160.3	370.8	1226.4	.3928	159
180	165.3	372.9	1227.1	.4035	155
185	170.3	375.3	1227.8	.4142	151
190	175.3	377.5	1228.5	.4250	148
195	180.3	379.7	1229.2	.4357	144
200	185.3	381.7	1229.8	.4464	141
210	195.3	386.0	1231.1	.4668	135
220	205.3	389.9	1232.8	.4872	129
230	215.3	393.8	1233.5	.5072	123
240	225.3	397.5	1234.6	.5270	119
250	235.3	401.1	1235.7	.5471	114
260	245.3	404.5	1236.8	.5670	110
270	255.3	407.9	1237.8	.5871	106
280	265.3	411.2	1238.8	.6070	102
290	275.3	414.4	1239.8	.6268	99
300	285.3	417.5	1240.7	.6469	96

CENTRAL AND MECHANICAL FORCES AND DEFINITIONS.

Acceleration.—Acceleration is the increase of velocity in a moving body caused by the continued action of the motive force. When bodies in motion pass through equal spaces in equal time, or, in other words, when the velocity of the body is the same during the period that the body is in motion, it is termed uniform motion, of which we have a familiar instance in the motion of the hands of a clock over the face of it; but a more correct illustration is the revolution of the earth on its axis. In the case of a body moving through unequal spaces in equal times, or with a varying velocity, if the velocity increase with the duration of the motion, it is termed accelerated motion; but if it decrease with the duration of the motion, it is termed retarded motion.

Affinity.—Affinity is a term used in chemistry to denote that kind of attraction by which the particles of different bodies unite, and form a compound possessing properties distinct from those of any of the substances which compose it. Thus, when an acid and alkali combine, a new substance is formed called a salt, perfectly different in its chemical properties from either an acid or an alkali; and, in consequence of the law of affinity, these bodies have a tendency to unite.

Angle.—If two lines drawn on a plain surface are so situated that they meet in a point, or would do so, if long enough, they form an opening, which is called an angle. One straight line meeting another which is perpendicular to it makes the angle on both sides equal; then these angles are each called a right angle, and in this case the one line is said to be perpendicular to the other, or, in the language of mechanics, the one line is said to be square with the

other; and if the one line be horizontal, the perpendicular is said to be plumb to it. The arc which measures a right angle is the quarter of the whole circumference, or is a quadrant, and contains 90 degrees; any angle measured by an arc less than this is acute (sharp), and if by an arc greater than a quadrant, obtuse (blunt).

Axle.—An axle is a shaft supporting a wheel; the wheel may turn on the axle, or be fastened to it, and the axle turn on bearings. Axles are viewed as having certain relations to girders in principle. Girders generally have their two ends resting on two points of support, and the load is either located at fixed distances from the props, or dispersed over the whole surface of the axle; the wheels may be considered the props and the journals the loaded parts. It is found that the inclined surface of the wheel-tire given by coning ranges from 1 to 12 to 1 to 20; and, as a matter of course, the direct tendency of the wheel under a load is to descend that incline, so that every vertical blow which the wheels may receive is compounded of two forces, viz., the one to crush the wheels in the direction of their vertical plane, and the other to move the lower parts of the wheels together. It will be seen that these two forces have a direct tendency to bend the axle somewhere between the wheels.

Capillary Attraction. — Capillary attraction is the property inherent in narrow tubes and porous substances, such as sponge, lamp-wicking, thread, etc., of raising oil, water, or other fluids above their natural level. Hence this principle is applied for obtaining a continuous supply of lubricating fluids between rubbing and revolving surfaces in motion, by means of a siphon constructed of wickings, worsted, or some other substance, one end of which is immersed in oil, and the other inserted in the tube through which the fluid is to be conducted.

Centre of Gravity.— The forces with which all bodies tend to fall to the earth may be considered parallel; hence every body may be considered as acted on by a system of parallel forces, whose resultant may be found, and these forces, in all positions of the body, act on the same points in the same vertical direction. There is, therefore, in every body a point through which the resultant always passes, in whatever position it is placed. This point is called the centre of gravity of the body. The centre of gravity of a uniform cylinder or prism is in its axis, and at the middle of its length; of a right cone or a pyramid it is also in the axis, but at one-fourth of the height from the base.

Dynamics.— Dynamics is that branch of mechanics which treats of forces in motion producing power and work. It comprehends the action of all kinds of machinery, manual and animal labor, in the transformation of physical work.

Energy.— This term is used to denote work, but the sense of it conveys an idea of a different virtue, namely, that of activity or vigor, which is power. We say that a man has a great deal of energy when he can accomplish much work in a short time, which is virtue of power; but if he accomplishes the same quantity of work in a much longer time, we do not give him credit for much energy. The term energy, if employed at all, ought to be applied to power alone; but as we have the expressive term power for that function, it is better to dispense with the term energy in dynamics.

Force.— Force is the cause of motion or change of motion in material bodies. Every change of motion, viz., every change in the velocity of a body, must be regarded as the effect of a force. On the other hand, rest, or the invariability of the state of motion of a body, must not be attributed to the absence of forces, for opposite forces

destroy each other and produce no effect. The gravity with which a body falls to the ground still acts, though the body rests; but this action is counteracted by the solidity of the material upon which it reposes. Forces that are balanced so as to produce rest are called statical forces or pressures, to distinguish them from moving, deflecting, accelerating, or retarding forces; *i. e.*, such as are producing motion, or a change in the direction or velocity of motion. This distinction is wholly artificial, for the same force may act in any of these modes; it may sometimes be a statical and sometimes an accelerating force.

Force is any action which can be expressed simply by weight, and is distinguished by a great variety of terms, such as attraction, repulsion, gravity, pressure, tension, compression, cohesion, adhesion, resistance, inertia, strain, stress, strength, thrust, burden, load, squeeze, pull, push, pinch, punch, etc., all of which may be measured or expressed by weight without regard to motion, time, power, or work.

Focus.— Focus in geometry is that point in the transverse axis of a conic section at which the double ordinate is equal to a perimeter, or to a third proportional to the transverse and conjugate axis.

Friction.— Friction is the resistance occasioned to the motion of a body when pressed upon the surface of another body which does not partake of its motion. Under these circumstances, the surfaces in contact have a certain tendency to adhere. Not being perfectly smooth, the imperceptible asperities which may be supposed to exist on all surfaces, however highly polished, become to some extent interlocked, and, in consequence, a certain amount of force is requisite to overcome the mutual resistance to motion of the two surfaces and to maintain the sliding motion even when it has been produced. By increasing

the pressure, the resistance to motion is increased also; and on the other hand, by rendering the surfaces smoother by lubrication, its amount is greatly diminished, but can never be entirely annulled.

Friction cannot be strictly called a force, unless that term be taken in a negative sense. The tendency of force, in the rigid meaning of the word, is to produce motion; whereas the tendency of friction is to destroy motion.

Friction Rollers.—The obstruction which a cylinder meets in rolling along a smooth plane is quite distinct in its character, and far inferior in its amount to that which is produced by the friction of the same cylinder drawn lengthwise along a plane. For example, in the case of wood rolling on wood, the resistance is to the pressure, if the cylinder be small, as 16 or 18 to 1000, and if the cylinder be large, this may be reduced to 6 to 1000. The friction from sliding, in the same cases, would be to the pressure as 2 to 10 or 3 to 10, according to the nature of the wood. Hence, by causing one body to roll on another, the resistance is diminished from 12 to 20 times. It is therefore a principle, in the composition of machines, that attrition should be avoided as much as possible, and rolling motions substituted whenever circumstances admit.

Gravity and Gravitation.—These terms are often used synonymously to denote the mutual tendency which all bodies in nature have to approach each other.

Gravity, Specific.—The specific gravity of a body is the ratio of its weight to an equal volume of some other body assumed as a conventional standard. The standard usually adopted for solids and liquids is rain or distilled water at a common temperature. In bodies of equal magnitudes, the specific gravities are directly as the weights or as their densities. In bodies of the same specific gravity the weights will be as the magnitudes. In bodies of equal

weights, the specific gravities are inversely as the magnitudes. The weights of different bodies are to each other in the compound ratio of their magnitudes and specific gravities. Hence, it is obvious that, speaking of the magnitude, weight, and specific gravity of a body, if any two of them are given, the third may be found.

A body immersed in a fluid will sink if its specific gravity be greater than that of the fluid; if it be less, the body will rise to the top, and be only partly immerged; and if the specific gravity of the body and fluid be equal, it will remain at rest in any part of the fluid in which it may be placed. When a body is heavier than a fluid, it loses as much of its weight when immersed as is equal to a quantity of the fluid of the same bulk or magnitude. If the specific gravity of the fluid be greater than that of the body, then the quantity of fluid displaced by the part immerged is equal to the weight of the whole body. And hence, as the specific gravity of the fluid is to that of the body, so is the whole magnitude of the body to the part immerged. The specific gravities of equal solids are as their parts immerged in the same fluid.

Gyration, the Centre of.—The centre of gyration is that point in which, if all the matter contained in a revolving system were collected, the same angular velocity will be generated in the same time by a given force acting at any place as would be generated by the same force acting similarly in the body or system itself. The distance of the centre of gyration from the point of suspension or the axis of motion, is a mean proportional between the distances of the centres of oscillation and gravity from the same point or axle.

Horse-power, or Power of a Horse.—The power of a horse when applied to draw loads, as well as when made the standard of comparison for determining the value of

other powers, has been variously stated. The relative strength of men and horses depends, of course, upon the manner in which their strength is applied. Thus, the worst way of applying the strength of a horse is to make him carry a weight up a steep hill; while the organization of the man fits him very well for that kind of labor. Three men climbing up a steep hill, each one having 100 pounds on his shoulder, will proceed faster than most horses with 300 pounds.

Hydrodynamics.— Hydrodynamics is that branch of general mechanics which treats of the equilibrium and motion of fluids. The terms hydrostatics and hydrodynamics have a signification corresponding to the statics and dynamics in the mechanics of solid bodies, viz., hydrostatics is that division of the science which treats of the equilibrium of fluids, and hydrodynamics that which relates to their forces and motion. It is, however, very usual to include the whole doctrine of the mechanics of fluids under the general term of hydrodynamics, and to denote the divisions relative to their equilibrium and motion by the terms hydrostatics and hydraulics.

Hyperbola.— A plane figure formed by cutting a section from a cone by a plane parallel to its axis, or to any plane within the cone, which passes through the cone's vertex. The curve of the hyperbola is such that the difference between the distances of any point in it from two given points is always equal to a given right line. If the vertices of two cones meet each other so that their axes form one continuous straight line, and the plane of the hyperbola cut from one of the cones be continued, it will cut the other cone, and form what is called the opposite hyperbola, equal and similar to the former; and the distance between the vertices of the two hyperbolæ is called the major axis, or transverse diameter. If the distance

between a certain point within the hyperbola, called the focus, and any point in the curve be subtracted from the distance of said point in the curve from the focus of the opposite hyperbola, the remainder will always be equal to a given quantity, that is, to the major axis; and the distance of either focus from the centre of the major axis is called the eccentricity. The line passing through the centre, perpendicular to the major axis, and having the distance of its extremities from those of the axis equal to the eccentricity, is called the minor axis, or conjugate diameter. An ordinate to the major axis, a double ordinate, and an absciss mean the same as the corresponding lines in the parabola.

Impact is the single instantaneous blow or stroke communicated from one body in motion to another either in motion or at rest.

Impenetrability.— In physics, one of the essential properties of matter or body. It is a property inferred from invariable experience, and resting on this incontrovertible fact, that no two bodies can occupy the same portion of space in the same instant of time. Impenetrability, as respects solid bodies, requires no proof: it is obvious to the touch. With regard to liquids, the property may be proved by very simple experiments. Let a vessel be filled to the brim with water, and a solid, incapable of solution in water, be plunged into it; a portion of the water will overflow exactly equal in bulk to the dimensions of the body immersed. If a cork be rammed hard into the neck of a vial full of water, the vial will burst, while its neck remains entire. The disposition of air to resist penetration may be illustrated in the following way: Let a tall glass vessel be nearly filled with water, on the surface of which a lighted taper is set to float; if over this glass a smaller cylindrical vessel, likewise of glass, be inverted and pressed

downwards, the contained air maintaining its place, the internal body of the water will descend while the rest will rise up at the sides, and the taper will continue to burn for some seconds encompassed by the whole mass of liquid.

Impetus.—Impetus is the product of the mass and velocity of a moving body, considered as instantaneous, in distinction from momentum, with reference to time, and force, with reference to capacity of continuing its motion. Impetus in gunnery is the altitude through which a heavy body must fall to acquire a velocity equal to that with which the ball is discharged from the piece.

Incidence.—The term incidence in mechanics is used to denote the direction in which a body or ray of light strikes another body, and is otherwise called inclination. In moving bodies their incidence is said to be perpendicular or oblique according as their lines of motion make a straight line or an angle at the point of contact.

Inclination.—Inclination denotes the mutual approach or tendency of two bodies, lines, or planes towards each other, so that the lines of their direction make at the point of contact an angle of greater or less magnitude.

Inclined Plane.—An inclined plane is one of the mechanical powers; a plane which forms an angle with the horizon. The force which accelerates the motion of a heavy body on an inclined plane, is to the force of gravity as the sine of the inclination of the plane to the radius, or as the height of the plane is to its length.

Inertia.—Inertia is that property of matter by which it tends when at rest to remain so, and when in motion to continue in motion.

Levers.—Levers are classified into three different kinds or orders. When the fulcrum is between the force and the weight, the lever is called a lever of the first order;

when the weight is between the force and the fulcrum, the lever is of the second order; when the force is between the weight and the fulcrum, the lever is of the third order. The levers of safety-valves for steam-boilers belong to this latter class.

Machines. — Machines are instruments employed to regulate motion so as to save either time or force. The maximum effect of machines is the greatest effect which can be produced by them. In all machines that work with a uniform motion there is a certain velocity, and a certain load of resistance that yields the greatest effect, and which are therefore more advantageous than any other. A machine may be so heavily charged that the motion resulting from the application of any given power will be but just sufficient to overcome it, and if any motion ensue, it will be very trifling, and the whole effect will be very small. If the machine is very lightly loaded, it may give great velocity to the load; but from the smallness of its quantity, the effect may still be very inconsiderable, consequently between these two loads there must be some intermediate one that will render the effect the greatest possible. This is equally true in the application of animal strength as in machines. The maximum effect of a machine is produced, when the weight or resistance to be overcome is four-ninths of that which the power, when fully exerted, is able to balance, or of that resistance which is necessary to reduce the machine to rest, and the velocity of the part of the machine to which the power is applied should be one-third of the greatest velocity of the power.

The moving power and the resistance being both given, if the machine be so constructed, that the velocity of the point to which the power is applied be to the velocity of the point to which the resistance is applied, as four times

the resistance to nine times the power, the machine will work to the greatest possible advantage. This is equally true when applied to the strength of animals; that is, a man, horse, or other animal, will do the greatest quantity of work, by continued labor, when his strength is opposed to a resistance equal to four-ninths of his natural strength, and his velocity equal to one-third of his greatest velocity when not impeded.

Mass.—Mass is the real quantity of matter in a body, and is proportioned to weight when compared in one or the same locality. Mass is a constant quantity, whilst weight varies with the force of gravity which produces it.

Matter.—Matter is that of which bodies are composed, and occupies space. Matter is recognized as substances in contradistinction from geometrical quantities and physical phenomena, such as color, shadow, light, heat, electricity, and magnetism.

Mechanical Powers.—Mechanical powers are usually denominated the lever, inclined plane, wheel and axle, pulley, screw, and wedge. The wheel and axle is, however, a revolving lever; the screw a revolving inclined plane, and the wedge a double inclined plane, thus reducing them to three in number, viz., lever, inclined plane, and pulley. All these machines act on the same fundamental principle of vertical velocities; accordingly, the weight multiplied into the space it moves through is equal to the power multiplied into the space it moves through. In all machines a portion of the effect is lost in overcoming the friction of the working parts; but in making a calculation upon them, it is made first as though no friction existed, a deduction being afterwards made.

Rules *for Finding the Effects of the Mechanical Powers.*
Inclined Plane.—As the length of the plane is to its height, so is the weight to the power.

Lever.— When the fulcrum (or support) of the lever is between the weight and the power, divide the weight to be raised by the power, and the quotient is the difference of leverage, or the distance from the fulcrum at which the power supports the weight. Or, multiply the weight by its distance from the fulcrum, and the power by its distance from the same point, and the weight and power will be to each other as their products.

When the fulcrum is at one extremity of the lever, and the power, or the weight, at the other. As the distance between the power, or weight, and the fulcrum is to the distance between the weight, or power, and the fulcrum, so is the effect to the power or the power to the effect.

Screw.— As the screw is an inclined plane wound round a cylinder, the length of the plane is found by adding the square of the circumference of the screw to the square of the distance between the threads, and, taking the square root of the sum, then the height is the distance between the consecutive threads.

Wedge.— When two bodies are forced from one another in a direction parallel to the back of the wedge, then the resistance is to the force as the length of the wedge is to half its back.

Wheel and Axle.— The power multiplied by the radius of the wheel is equal to the weight multiplied by the radius of the axle; as the radius of the wheel is to the radius of the axle, so is the effect to the power. When a series of wheels and axles act upon each other, either by belts or teeth, the weight or velocity will be to the power or unity as the product of the radii, or circumferences of the wheels, to the product of the radii or circumferences of the axles.

Mechanics.—Mechanics is that branch of natural philosophy which treats of the three simple physical elements,

force, motion, and time, with their combinations, constituting power, space, and work.

Modulus.—The modulus of the elasticity of any substance is a column of the same substance capable of producing a pressure on its base, which is to the weight causing a certain degree of compression as the length of the substance is to the diminution of its length.

Momentum.—Momentum, in mechanics, is the same as impetus or quantity of motion, and is generally estimated by the product of the velocity and the mass of the body. This is a subject which has led to various controversies between philosophers,—some estimating it by the mass into the velocity as stated above, while others maintain that it varies as the mass into the square of the velocity. But this difference seems to have arisen rather from a misconception of the term, than from any other cause. Those who maintain the former doctrine, understand momentum to signify the momentary impact; and the advocates of the latter doctrine recognize it as the sum of all the impulses, till the motion of the body is destroyed.

Motion.—Motion, in mechanics, is a change of place, or it is that property inherent in matter by which it passes from one point of space to another. Motion is expressed by the following terms: Move, going, walking, passing, transit, involution and evolution, run, locomotion, flux, rolling, flow, sweep, wander, shift, flight, current, etc.

Absolute motion is the absolute change of place in a moving body independent of any other motion whatever; in which general sense, however, it never falls under our observation. All those motions which we consider as absolute, are in fact only relative, being referred to the earth, which is itself in motion. By absolute motion, therefore, we must only understand that which is so with regard to some fixed point upon the earth, this

being the sense in which it is interpreted by writers on this subject.

Accelerated motion is that which is continually receiving constant accessions of velocity.

Angular motion is the motion of a body as referred to a centre, about which it revolves.

Compound motion is that which is produced by two or more powers acting in different directions.

Natural motion is that which is natural to bodies or that which arises from the action of gravity.

Parallel Motions.—Contrivances of this kind are required for the conversion of rotary and alternating angular motion into rectilineal motion, and the converse; but the absolute necessity there is of guiding the path of a piston in a steam-engine has called forth more attention to the principles and mechanism of parallel motions than would otherwise, in all probability, have been awarded to the subject.

Relative motion is the change of relative place in one or more moving bodies.

Retarded motion is that which suffers continual diminution of velocity, the laws of which are the reverse of those for accelerated motion.

Rotary Motion, turning as a wheel on its axis, pertaining to or resembling the motion of a wheel. Rotary motions were favorite ones with ancient philosophers. They considered a circle as the most perfect of all figures, and erroneously concluded that a body in motion would naturally revolve in one.

To the substitution of circular for straight motions, and of continuous for alternating ones, may be attributed nearly all the conveniences and elegancies of civilized life. It is not too much to assert that the present advanced state of science and the arts is due to revolving mechan-

ism. From the earliest times it had been an object to convert, whenever practicable, the rectilinear and reciprocating movements of machines into circular and continuous ones. Old mechanics seem to have been led to this result by that tact or natural sagacity that is more or less common to all times and people. Thus the dragging of heavy loads on the ground led to the adoption of wheels and rollers, — hence carts and carriages. The rotary movements of the drill superseded the alternating one of the punch and gouge, in making perforations; the whetstone gave way to the revolving grindstone; the turning-lathe produced round forms infinitely more accurate and more expeditiously than the uncertain and irregular carving or cutting with the knife.

Uniform motion is when a body moves continually with the same velocity, passing over equal spaces in equal times.

Oscillation, Centre of. — The centre of oscillation is that point in a vibrating body in which, if the whole were concentrated and attached to the same axis of motion, it would vibrate in the same time the body does in its natural state. The centre of oscillation is situated in a right line passing through the centre of gravity, and perpendicular to the axis of motion.

Pendulum. — If any heavy body, suspended by an inflexible rod from a fixed point, be drawn aside from the vertical position, and then let fall, it will descend in the arc of a circle, of which the point of suspension is the centre. On reaching the vertical position, it will have acquired a velocity equal to that which it would have acquired by falling vertically through the versed sine of the arc which it has described, in consequence of which it will continue to move in the same arc, until the whole velocity is destroyed; and if no other force than gravity were in operation, this would take place when the body

reached a height on the opposite side of the vertical height equal to that from which it fell. Having reached this height, it would again descend, and so continue to vibrate forever; but in consequence of the friction of the axis and the resistance of the air, each successive vibration will be diminished, and the body soon be brought to rest in the vertical position. A body thus suspended and caused to vibrate is called a pendulum; and the passage from the greatest distance from the vertical on the one side to the greatest distance on the other is called an oscillation.

Percussion.—The centre of percussion is that point in a body revolving about an axis at which, if it struck an immovable obstacle, all its motion would be destroyed, or it would not incline either way. When an oscillating body vibrates with a given angular velocity, and strikes an obstacle, the effect of the impact will be the greatest, if it be made at the centre of percussion. For in this case the obstacle receives the whole revolving motion of the body; whereas, if the blow be struck at any other point, a part of the motion will be employed in endeavoring to continue the rotation.

Perpetual Motion.—In mechanics, a machine which, when set in motion, would continue to move forever, or, at least, until destroyed by the friction of its parts, without the aid of any exterior cause, would constitute perpetual motion. The discovery of perpetual motion has always been a celebrated problem in mechanics, on which many ingenious, though in general ill-instructed, persons have consumed their time; but all the labor bestowed on it has proved abortive. In fact, the impossibility of its existence has been fully demonstrated from the known laws of matter. In speaking of perpetual motion, it is to be understood that, from among the forces by which motion may be produced, we are to exclude not only air and

water, but other natural agents, as heat, atmospheric changes, etc. The only admissible agents are the inertia of matter, and its attractive forces, which may all be considered of the same kind as gravitation. It is an admitted principle in philosophy, that action and reaction are equal, and that, when motion is communicated from one body to another, the first loses just as much as is gained by the second. But every moving body is continually retarded by two passive forces,—the resistance of the air and friction. In order, therefore, that motion may be continued without diminution, one of two things is necessary—either that it be maintained by an exterior force, (in which case it would cease to be what we understand by a perpetual motion,) or that the resistance of the air and friction be annihilated, which is practically impossible.

The motion cannot be perpetuated till these retarding forces are compensated, and they can only be compensated by an exterior force, as the force communicated to any body cannot be greater than the generating force, which is only sufficient to continue the same quantity of motion when there is no resistance. The error of confounding mere pressure with energy available to produce power is the main origin of the majority of attempts at perpetual motion, and even sometimes causes, among confused minds, exaggerated expectations about the effects to be obtained from mechanical contrivances. A wound-up spring is exactly equivalent to a weight. It may exert a certain pressure, great in proportion to its size and strength; but unless it is allowed to unwind it, it cannot produce motion or power. It is the same with compressed air or gases; they are, in fact, nothing but wound-up springs, with this difference, however, that, in place of needing mechanical power to wind them up, we may use either heat, chemical agencies, or electricity.

Pneumatics.— Pneumatics is the science which treats of the mechanical properties of elastic fluids, and particularly of atmospheric air. Elastic fluids are divided into two classes — permanent gases, and vapors. The gases cannot be converted into the liquid state by any known process; whereas the vapors are readily reduced to the liquid form by pressure or diminution of temperature. In respect of their mechanical properties, there is, however, no essential difference between the two classes. Elastic fluids, in a state of equilibrium, are subject to the action of two forces, namely, gravity, and a molecular force acting from particle to particle. Gravity acts on the gases in the same manner as on all other substances; but the action of the molecular forces is altogether different from that which takes place among the elementary particles of solids and liquids; for, in the case of solid bodies, the molecules strongly attract each other, (whence results their cohesion,) and, in the case of liquids, exert a feeble or evanescent attraction, so as to be indifferent to internal motion; but, in the case of the gases, the molecular forces are repulsive, and the molecules, yielding to the action of these forces, tend incessantly to recede from each other, and, in fact, do recede until their further separation is prevented by an exterior obstacle. Thus, air confined within a close vessel exerts a constant pressure against the interior surface, which is not sensible, only because it is balanced by the equal pressure of the atmosphere on the exterior surface. This pressure exerted by the air against the sides of a vessel within which it is confined is called its elasticity — its elastic force or tension.

Power.—Power is the product of force and velocity; that is to say, a force multiplied by the velocity with which it is acting. The term horse-power is a unit of power, established by James Watt to be equivalent to a

force of 33,000 pounds acting with a velocity of one foot per minute, or 150 pounds acting with a velocity of 220 feet per minute, which is the same as a force of 550 pounds acting with a velocity of one foot per second. Man-power is a unit of power established by Morin to be equivalent to 50 foot-pounds of power, or 50 effects; that is to say, a man turning a crank with a force of 50 pounds, with a velocity of one foot per second, is a standard man-power.

Prime Movers.— Prime movers are those machines from which we obtain power, through their adaptation to the transformation of some available natural force into that kind of effort which develops mechanical power.

Statics is the science of forces in equilibrium. It treats of the strength of materials, of bridges, and of girders; the stability of walls, steeples, and towers; the static momentum of levers, with their combinations into weighing-scales, windlasses, pulleys, funicular machines, inclined planes, screws, catenaria, and all kinds of gearing.

Tools.— By the term tools, according to the definition given by Rennie, we understand instruments employed in the manual arts for facilitating mechanical operations by means of percussion, penetration, separation, and abrasion, of the substances operated upon, and for all which operations various motions are required to be imparted either to the tool or to the work.

Torsion.— Torsion, in mechanics, is the twisting or wrenching of a body by the exertion of a lateral force. If a slender rod of metal, suspended vertically, and having its upper end fixed, be twisted through a certain angle by a force acting in a plane perpendicular to its axis, it will, on the removal of the force, untwist itself, or return in the opposite direction with a greater or less velocity, and after a series of oscillations will come to rest in its original

position. The limits of torsion within which the body will return to its original state depend on its elasticity. A fine wire of a few feet in length may be twisted through several revolutions, without impairing its elasticity; and within those limits the force evolved is found to be perfectly regular, and directly proportional to the angular displacement from the position of rest. If the angular displacement exceeds a certain limit (as in a wire of lead, for example, before disruption takes place), the particles will assume a new arrangement, or take a set, and will not return to their original position on the withdrawal of the disturbing force.

Velocity.— Velocity is rate of motion. Velocity is independent of space and time, but in order to obtain its value or expression as a quantity, we compare space with time. Thus, when the value of the velocity of a moving body is required, we measure the space which the body passes through, and divide that space by the time of passage, and the quotient is the velocity. Velocity, or rate of motion, is expressed by a variety of terms: speed, swiftness, rapidity, fleetness, speediness, quickness, haste, hurry, race, forced march, gallop, trot, run, rush, scud, dash, spring, etc.

Weight.— The weight of a body is the force of attraction between the earth and that body. The weight of a body is greatest at the surface of the earth, and decreases above or below that surface. Above the surface, the weight decreases as the square of its distance from the centre of the earth, and below the surface the weight decreases simply as its distance from the centre.

Weights and Measures.— The weights and measures of this country are identical with those of England. In both countries they repose, in fact, upon actually existing masses of metal (brass), which have been individually

declared by law to be the units of the system. In scientific theory, they are supposed to rest upon a permanent and universal law of nature — the gravitation of distilled water at a certain temperature and under a certain atmospheric pressure. In this aspect, the origination is with the grains, which must be such that 252,458 of these units of brass will be in just equilibrium with a cubic inch of distilled water, when the mercury stands at 30 inches in a barometer, and at 62 degrees in a thermometer of Fah. Unfortunately, the expounders of this theory in England used only the generic term brass, and failed to define the specific gravity of the metal to be employed; the consequence of this omission is to leave room for an error of $\frac{1}{100000}$ in every attempt to reproduce or compare the results. This is the minimum possible error; the maximum would be a fraction of the difference in specific gravity between the heaviest and lightest brass that can be cast.

Work.— Work is force acting through space, and is measured by multiplying the measure of the force by the measure of the space. Work is said to be performed when a pressure is exerted upon a body, and the body is thereby moved through space.

Work done is expressed by the following terms: hauled, dragged, raised, heaved, tilted, broken, crushed, thrown, wrought, fermented, labored, etc., or any expression which implies the three simple elements of force, velocity, and time. Power multiplied by the time of action is work; work divided by time is power. If work was independent of time, then any amount of work could be accomplished in no time. The greatest amount of work known to have been accomplished in the shortest time is that in the explosion of nitro-glycerine, which is instantaneous to our perception; but it required time, notwithstanding.

Workmanday. — A laborer working eight hours per day can exert a power of 50 foot-pounds. A day's work will then be $50 \times 8 \times 60 \times 60 = 1,440,000$ foot-pounds of work, which may be termed a workmanday. All kinds of heavy work can be estimated in workmandays, such as the building of a house, a bridge, a steamboat, canal and railroad excavations and embankments, loading or unloading a ship, powder and steam-boiler explosions, the capability of heavy ordnance, etc.

The magnitude of the unit workmanday is easily conceived, because it is that amount of work which a laborer can accomplish in one day. Work expressed in foot-pounds, divided by 1,440,000, gives the work in workmandays.

MENSURATION OF THE CIRCLE, CYLINDER, SPHERE, ETC.

1. **The areas of circles** are to each other as the squares of their diameters.

2. **The diameter of a circle** being 1, its circumference equals 3.1416.

3. **The diameter of a circle** is equal to .31831 of its circumference.

4. **The square of the diameter of a circle** being 1, its area equals .7854.

5. **The square root of the area of a circle** multiplied by 1.12837 equals its diameter.

6. **The diameter of a circle** multiplied by .8862, or the circumference multiplied by .2821, equals the side of a square of equal area.

7. **Take the sum** of the squares of half the chord and versed sine, and divide by the versed sine, the quotient equals the diameter of corresponding circle.

8. **Subtract the chord** of the whole arc of a circle from eight times the chord of half the arc, one-third of the remainder equals the length of the arc; or,

9. **The number of degrees** contained in the arc of a circle, multiplied by the diameter of the circle and by .008727, the product equals the length of the arc in equal terms of unity.

10. **The length of the arc** of a sector of a circle multiplied by its radius, equals twice the area of the sector.

11. **The area of the segment** of a circle equals the area of the sector, minus the area of a triangle whose vertex is the centre, and whose base equals the chord of the segment; or,

12. **The area of a segment** may be obtained by dividing the height of the segment by the diameter of the circle, and multiplying the corresponding tabular area by the square of the diameter.

13. **The sum of the diameters** of two concentric circles multiplied by their difference, and by .7854, equals the area of the ring or space between them.

14. **The sum of the thickness** and internal diameter of a cylindric ring multiplied by the square of its thickness, and by 2.4674, equals its solidity.

15. **The circumference of a cylinder** multiplied by its length or height equals its convex surface.

16. **The area of the end** of a cylinder multiplied by its depth equals its cubical capacity.

17. **The square of the diameter** of a cylinder multiplied by its length, and divided by any other required length, the square root of the quotient equals the diameter of the other cylinder of equal contents or capacity.

18. **The square of the diameter of a sphere** multiplied by 3.1416 equals its convex surface.

19. **The cube of the diameter** of a sphere multiplied by .5236 equals its solid contents.

20. **The height of any spherical segment or zone** multiplied by the diameter of the sphere of which it is a part, and by 3.1416, equals the area or convex surface of the segment; or,

21. **The height of the segment** multiplied by the circumference of the sphere of which it is a part, equals the area.

22. **The solidity of any spherical segment** is equal to three times the square of the radius of its base, plus the square of its height, and multiplied by its height and by .5236.

23. **The solidity of a spherical zone** equals the sum of the squares of the radii of its two ends, and one-third the square of its height multiplied by the height and by 1.5708.

24. **The capacity of a cylinder** 1 foot in diameter and 1 foot in length equals 5.875 of a United States gallon.

25. **The capacity of a cylinder** 1 inch in diameter and 1 inch in length equals .0034 of a United States gallon.

26. **The capacity of a sphere** 1 foot in diameter equals 3.9156 United States gallons.

27. **The capacity of a sphere** 1 inch in diameter equals .002165 of a United States gallon; hence,

28. **The capacity of any other cylinder** in United States gallons is obtained by multiplying the square of its diameter by its length; and the capacity of any other spherical body may be calculated by multiplying the cube of its diameter by its length, and by the number of United States gallons in the unity of its measurement, as contained in the last four paragraphs.

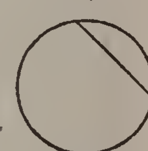
PROPERTIES OF THE CIRCLE.

A circular vessel will contain a greater quantity than a vessel of any other shape, made of the same amount of material; that is to say, if an iron plate 10 feet long was rolled into a cylinder, and a bottom put in it, it would hold more water than if the 10 feet plate had been bent square, or any other shape.

The diameter of a circle is a straight line drawn through its centre, touching both sides.....

The radius of a circle is half the diameter, or the distance from the centre to the perimeter..

A chord is a straight line joining any two places in the circumference of a circle............



The versed sine is a perpendicular joining the middle of the chord and circumference of a circle..

An arc is any part of the circumference of a circle..

Multiply the diameter by 3.1416, and the product is the circumference.

Multiply the circumference by .31831, and the result is the diameter.

Multiply the square of the diameter, viz., the diameter multiplied by itself, by .7854, and the product is the area.

Multiply the square root of the area by 1.12837, and the product is the diameter.

Multiply the diameter by .8862, and the product is the side of a square of equal area.

Multiply the side of a square by 1.128, and the product is the diameter of a circle of equal area.

TABLE

CONTAINING THE DIAMETERS, CIRCUMFERENCES, AND AREAS OF CIRCLES FROM $\frac{1}{16}$ OF AN INCH TO 20 INCHES, ADVANCING BY $\frac{1}{16}$ OF AN INCH UP TO 10 INCHES, AND BY $\frac{1}{8}$ OF AN INCH FROM 10 TO 20 INCHES.

DIAM.	CIRCUM.	AREA.	DIAM.	CIRCUM.	AREA.
Inch.			Inch.		
$\frac{1}{16}$	.1963	.0030	$\frac{7}{16}$	7.6576	4.6664
$\frac{1}{8}$	.3927	.0122	$\frac{1}{2}$	7.8540	4.9087
$\frac{3}{16}$	.5890	.0276	$\frac{9}{16}$	8.0503	5.1573
$\frac{1}{4}$	.7854	.0490	$\frac{5}{8}$	8.2467	5.4119
$\frac{5}{16}$	.9817	.0767	$\frac{11}{16}$	8.4430	5.6727
$\frac{3}{8}$	1.1781	.1104	$\frac{3}{4}$	8.6394	5.9395
$\frac{7}{16}$	1.3744	.1503	$\frac{13}{16}$	8.8357	6.2126
$\frac{1}{2}$	1.5708	.1963	$\frac{7}{8}$	9.0321	6.4918
$\frac{9}{16}$	1.7671	.2485	$\frac{15}{16}$	9.2284	6.7772
$\frac{5}{8}$	1.9635	.3068	3	9.4248	7.0686
$\frac{11}{16}$	2.1598	.3712	$\frac{1}{16}$	9.6211	7.3662
$\frac{3}{4}$	2.3562	.4417	$\frac{1}{8}$	9.8175	7.6699
$\frac{13}{16}$	2.5525	.5185	$\frac{3}{16}$	10.0138	7.9798
$\frac{7}{8}$	2.7489	.6013	$\frac{1}{4}$	10.2120	8.2957
$\frac{15}{16}$	2.9452	.6903	$\frac{5}{16}$	10.4065	8.6179
1	3.1416	.7854	$\frac{3}{8}$	10.6029	8.9462
$\frac{1}{16}$	3.3379	.8861	$\frac{7}{16}$	10.7992	9.2806
$\frac{1}{8}$	3.5343	.9940	$\frac{1}{2}$	10.9956	9.6211
$\frac{3}{16}$	3.7306	1.1075	$\frac{9}{16}$	11.1919	9.9678
$\frac{1}{4}$	3.9270	1.2271	$\frac{5}{8}$	11.3883	10.3206
$\frac{5}{16}$	4.1233	1.3529	$\frac{11}{16}$	11.5846	10.6796
$\frac{3}{8}$	4.3197	1.4848	$\frac{3}{4}$	11.7810	11.0446
$\frac{7}{16}$	4.5160	1.6229	$\frac{13}{16}$	11.9773	11.4159
$\frac{1}{2}$	4.7124	1.7671	$\frac{7}{8}$	12.1737	11.7932
$\frac{9}{16}$	4.9087	1.9175	$\frac{15}{16}$	12.3700	12.1768
$\frac{5}{8}$	5.1051	2.0739	4	12.5664	12.5664
$\frac{11}{16}$	5.3014	2.2365	$\frac{1}{16}$	12.7627	12.9622
$\frac{3}{4}$	5.4978	2.4052	$\frac{1}{8}$	12.9591	13.3640
$\frac{13}{16}$	5.6941	2.5801	$\frac{3}{16}$	13.1554	13.7721
$\frac{7}{8}$	5.8905	2.7611	$\frac{1}{4}$	13.3518	14.1862
$\frac{15}{16}$	6.0868	2.9483	$\frac{5}{16}$	13.5481	14.6066
2	6.2832	3.1416	$\frac{3}{8}$	13.7445	15.0331
$\frac{1}{16}$	6.4795	3.3411	$\frac{7}{16}$	13.9408	15.4657
$\frac{1}{8}$	6.6759	3.5465	$\frac{1}{2}$	14.1372	15.9043
$\frac{3}{16}$	6.8722	3.7582	$\frac{9}{16}$	14.3335	16.3492
$\frac{1}{4}$	7.0686	3.9760	$\frac{5}{8}$	14.5299	16.8001
$\frac{5}{16}$	7.2640	4.2001	$\frac{11}{16}$	14.7262	17.2573
$\frac{3}{8}$	7.4613	4.4302	$\frac{3}{4}$	14.9226	17.7205

TABLE—(*Continued*)

CONTAINING THE DIAM., CIRCUMFERENCES, AND AREAS OF CIRCLES.

Diam.	Circum.	Area.	Diam.	Circum.	Area.
Inch.			Inch.		
$\frac{13}{16}$	15.1189	18.1900	$\frac{7}{16}$	23.3656	43.4455
$\frac{7}{8}$	15.3153	18.6655	$\frac{1}{2}$	23.5620	44.1787
$\frac{15}{16}$	15.5716	19.1472	$\frac{9}{16}$	23.7583	44.9181
5	15.7080	19.6350	$\frac{5}{8}$	23.9547	45.6636
$\frac{1}{16}$	15.9043	20.1290	$\frac{11}{16}$	24.1510	46.4153
$\frac{1}{8}$	16.1007	20.6290	$\frac{3}{4}$	24.3474	47.1730
$\frac{3}{16}$	16.2970	21.1252	$\frac{13}{16}$	24.5437	47.9370
$\frac{1}{4}$	16.4934	21.6475	$\frac{7}{8}$	24.7401	48.7070
$\frac{5}{16}$	16.6897	22.1661	$\frac{15}{16}$	24.9364	49.4833
$\frac{3}{8}$	16.8861	22.6907	**8**	25.1328	50.2656
$\frac{7}{16}$	17.0824	23.2215	$\frac{1}{16}$	25.3291	51.0541
$\frac{1}{2}$	17.2788	23.7583	$\frac{1}{8}$	25.5255	51.8486
$\frac{9}{16}$	17.4751	24.3014	$\frac{3}{16}$	25.7218	52.8994
$\frac{5}{8}$	17.6715	24.8505	$\frac{1}{4}$	25.9182	53.4562
$\frac{11}{16}$	17.8678	25.4058	$\frac{5}{16}$	26.1145	54.2748
$\frac{3}{4}$	18.0642	25.9672	$\frac{3}{8}$	26.3109	55.0885
$\frac{13}{16}$	18.2605	26.5348	$\frac{7}{16}$	26.5072	55.9138
$\frac{7}{8}$	18.4569	27.1085	$\frac{1}{2}$	26.7036	56.7451
$\frac{15}{16}$	18.6532	27.6884	$\frac{9}{16}$	26.8999	57.5887
6	18.8496	28.2744	$\frac{5}{8}$	27.0963	58.4264
$\frac{1}{16}$	19.0459	28.8665	$\frac{11}{16}$	27.2926	59.7762
$\frac{1}{8}$	19.2423	29.4647	$\frac{3}{4}$	27.4890	60.1321
$\frac{3}{16}$	19.4386	30.0798	$\frac{13}{16}$	27.6853	60.9943
$\frac{1}{4}$	19.6350	30.6796	$\frac{7}{8}$	27.8817	61.8625
$\frac{5}{16}$	19.8313	31.2964	$\frac{15}{16}$	28.0780	62.7369
$\frac{3}{8}$	20.0277	31.9192	**9**	28.2744	63.6174
$\frac{7}{16}$	20.2240	32.5481	$\frac{1}{16}$	28.4707	64.5041
$\frac{1}{2}$	20.4204	33.1831	$\frac{1}{8}$	28.6671	65.3968
$\frac{9}{16}$	20.6167	33.8244	$\frac{3}{16}$	28.8634	66.2957
$\frac{5}{8}$	20.8131	34.4717	$\frac{1}{4}$	29.0598	67.2007
$\frac{11}{16}$	21.0094	35.1252	$\frac{5}{16}$	29.2561	68.1120
$\frac{3}{4}$	21.2058	35.7847	$\frac{3}{8}$	29.4525	69.0293
$\frac{13}{16}$	21.4021	36.4505	$\frac{7}{16}$	29.6488	69.9528
$\frac{7}{8}$	21.5985	37.1224	$\frac{1}{2}$	29.8452	70.8823
$\frac{15}{16}$	21.7948	37.8005	$\frac{9}{16}$	30.0415	71.8181
7	21.9912	38.4846	$\frac{5}{8}$	30.2379	72.7599
$\frac{1}{16}$	22.1875	39.1749	$\frac{11}{16}$	30.4342	73.7079
$\frac{1}{8}$	22.3839	39.8713	$\frac{3}{4}$	30.6306	74.6620
$\frac{3}{16}$	22.5802	40.5469	$\frac{13}{16}$	30.8269	75.6223
$\frac{1}{4}$	22.7766	41.2825	$\frac{7}{8}$	31.0233	76.5887
$\frac{5}{16}$	22.9729	41.9974	$\frac{15}{16}$	31.2196	77.5613
$\frac{3}{8}$	23.1693	42.7184	**10**	31.4160	78.5400

TABLE—(*Continued*)

CONTAINING THE DIAM., CIRCUMFERENCES, AND AREAS OF CIRCLES.

DIAM.	CIRCUM.	AREA.	DIAM.	CIRCUM.	AREA.
Inch.			Inch.		
$\frac{1}{8}$	31.8087	80.5157	$\frac{3}{8}$	48.3021	185.6612
$\frac{1}{4}$	32.2014	82.5160	$\frac{1}{2}$	48.6948	188.6923
$\frac{3}{8}$	32.5941	84.5409	$\frac{5}{8}$	49.0875	191.7480
$\frac{1}{2}$	32.9868	86.5903	$\frac{3}{4}$	49.4802	194.8282
$\frac{5}{8}$	33.3795	88.6643	$\frac{7}{8}$	49.8729	197.9330
$\frac{3}{4}$	33.7722	90.7627	**16**	50.2656	201.0624
$\frac{7}{8}$	34.1649	92.8858	$\frac{1}{8}$	50.6583	204.2162
11	34.5576	95.0334	$\frac{1}{4}$	51.0510	207.3946
$\frac{1}{8}$	34.9503	97.2053	$\frac{3}{8}$	51.4437	210.5976
$\frac{1}{4}$	35.3430	99.4021	$\frac{1}{2}$	51.8364	213.8251
$\frac{3}{8}$	35.7357	101.6234	$\frac{5}{8}$	52.2291	217.0772
$\frac{1}{2}$	36.1284	103.8691	$\frac{3}{4}$	52.6218	220.3537
$\frac{5}{8}$	36.5211	106.1394	$\frac{7}{8}$	53.0145	223.6549
$\frac{3}{4}$	36.9138	108.4342	**17**	53.4072	226.9806
$\frac{7}{8}$	37.3065	110.7536	$\frac{1}{8}$	53.7999	230.3308
12	37.6992	113.0976	$\frac{1}{4}$	54.1926	233.7055
$\frac{1}{8}$	38.0919	115.4660	$\frac{3}{8}$	54.5853	237.1049
$\frac{1}{4}$	38.4846	117.8590	$\frac{1}{2}$	54.9780	240.5287
$\frac{3}{8}$	38.8773	120.2766	$\frac{5}{8}$	55.3707	243.9771
$\frac{1}{2}$	39.2700	122.7187	$\frac{3}{4}$	55.7634	247.4500
$\frac{5}{8}$	39.6627	125.1854	$\frac{7}{8}$	56.1561	250.9475
$\frac{3}{4}$	40.0554	127.6765	**18**	56.5488	254.4696
$\frac{7}{8}$	40.4481	130.1923	$\frac{1}{8}$	56.9415	258.0161
13	40.8408	132.7326	$\frac{1}{4}$	57.3342	261.5872
$\frac{1}{8}$	41.2338	135.2974	$\frac{3}{8}$	57.7269	265.1829
$\frac{1}{4}$	41.6262	137.8867	$\frac{1}{2}$	58.1196	268.8031
$\frac{3}{8}$	42.0189	140.5007	$\frac{5}{8}$	58.5123	272.4479
$\frac{1}{2}$	42.4116	143.1391	$\frac{3}{4}$	58.9056	276.1171
$\frac{5}{8}$	42.8043	145.8021	$\frac{7}{8}$	59.2977	279.8110
$\frac{3}{4}$	43.1970	148.4896	**19**	59.6904	283.5294
$\frac{7}{8}$	43.5897	151.2017	$\frac{1}{8}$	60.0831	287.2723
14	43.9824	153.9384	$\frac{1}{4}$	60.4758	291.0397
$\frac{1}{8}$	44.3751	156.6995	$\frac{3}{8}$	60.8685	294.8312
$\frac{1}{4}$	44.7676	159.4852	$\frac{1}{2}$	61.2612	298.6483
$\frac{3}{8}$	45.1605	162.2956	$\frac{5}{8}$	61.6539	302.4894
$\frac{1}{2}$	45.5532	165.1303	$\frac{3}{4}$	62.0466	306.3550
$\frac{5}{8}$	45.9459	167.9896	$\frac{7}{8}$	62.4393	310.2452
$\frac{3}{4}$	46.3386	170.8735	**20**	62.8320	314.1600
$\frac{7}{8}$	46.7313	173.7820			
15	47.1240	176.7150			
$\frac{1}{8}$	47.5167	179.6725			
$\frac{1}{4}$	47.9094	182.6545			

LOGARITHMS.

The logarithm of a number is the exponent of a power to which another given invariable number must be raised in order to produce the first number. Thus, in the common system of logarithms, in which the invariable number is 10, the logarithm of 1000 is 3, because 10 raised to the third power is 1000. In general, if $a^x = y$, in which equation a is a given invariable number, then x is the logarithm of y. All absolute numbers, whether positive or negative, whole or fractional, may be produced by raising an invariable number to suitable powers. The invariable number is called the base of the system of logarithms; it may be any number whatever greater or less than unity; but having been once chosen, it must remain the same for the formation of all numbers in the same system. Whatever number may be selected for the base, the logarithm of the base is 1, and the logarithm of 1 is 0.

These properties of logarithms are of very great importance in facilitating the arithmetical operations of multiplication and division. For, if a multiplication is to be effected, it is only necessary to take from the logarithmic tables the logarithms of the factors, and add them into one sum, which gives the logarithm of the required product; and, on finding in the table the number corresponding to this new logarithm, the product itself is obtained. Thus, by means of a table of logarithms, the operation of multiplication is performed by simple addition. In like manner, if one number is to be divided by another, it is only necessary to subtract the logarithm of the divisor from that of the dividend, and to find in the table the number corresponding to this difference, which number is the quotient required. Thus, the quotient of a division is obtained by simple subtraction.

LOGARITHMS OF NUMBERS FROM 0 TO 1000.*

No.	0	1	2	3	4	5	6	7	8	9	Prop.
0	0	00000	30103	47712	60206	69897	77815	84510	90309	95424	
10	00000	00432	00860	01283	01703	02118	02530	02938	03342	03742	415
11	04139	04532	04921	05307	05690	06069	06445	06818	07188	07554	379
12	07918	08278	08636	08990	09342	09691	10037	10380	10721	11059	349
13	11394	11727	12057	12385	12710	13033	13353	13672	13987	14301	323
14	14613	14921	15228	15533	15836	16136	16435	16731	17026	17318	300
15	17609	17897	18184	18469	18752	19033	19312	19590	19865	20139	281
16	20412	20682	20951	21218	21484	21748	22010	22271	22530	22788	264
17	23045	23299	23552	23804	24054	24303	24551	24797	25042	25285	249
18	25527	25767	26007	26245	26481	26717	26951	27184	27415	27646	236
19	27875	28103	28330	28555	28780	29003	29225	29446	29666	29885	223
20	30103	30319	30535	30749	30963	31175	31386	31597	31806	32014	212
21	32222	32428	32633	32838	33041	33243	33445	33646	33845	34044	202
22	34242	34439	34635	34830	35024	35218	35410	35602	35793	35983	194
23	36173	36361	36548	36735	36921	37106	37291	37474	37657	37839	185
24	38021	38201	38381	38560	38739	38916	39093	39269	39445	39619	177
25	39794	39967	40140	40312	40483	40654	40824	40993	41162	41330	171
26	41497	41664	41830	41995	42160	42324	42488	42651	42813	42975	164
27	43436	43296	43456	43616	43775	43933	44090	44248	44404	44560	158
28	44716	44870	45024	45178	45331	45484	45636	45788	45939	46089	153
29	46240	46389	46538	46686	46834	46982	47129	47275	47421	47567	148
30	47712	47856	48000	48144	48287	48430	48572	48713	48855	48995	143
31	49136	49276	49415	49554	49693	49831	49968	50105	50242	50379	138
32	50515	50650	50785	50920	51054	51188	51321	51454	51587	51719	134
33	51851	51982	52113	52244	52374	52504	52633	52763	52891	53020	130
34	53148	53275	53102	53529	53655	53781	53907	54033	54157	54282	126
35	54407	54530	54654	54777	54900	55022	55145	55266	55388	55509	122
36	55630	55750	55870	55990	56410	56229	56348	56466	56584	56702	119
37	56820	56937	57054	57170	57287	57403	57518	57634	57749	57863	116
38	57978	58002	58206	58319	58433	58546	58658	58771	58883	58995	113
39	59106	59217	59328	59439	59549	59659	59769	59879	59988	60097	110
40	60206	60314	60422	60530	60638	60745	60852	60959	61066	61172	107
41	61278	61384	61489	61595	61700	61804	61909	62013	62117	62221	104
42	62325	62428	62531	62634	62736	62838	62941	63042	63144	63245	102
43	63347	63447	63548	63648	63749	63848	63948	64048	64147	64246	99
44	64345	64443	64542	64640	64738	64836	64933	65030	65127	65224	98
45	65321	65417	65513	65609	65075	65801	65896	65991	66086	66181	96
46	66276	66370	66464	66558	66651	66745	66838	66931	67024	67117	94
47	67210	67302	67394	67486	67577	67669	67760	67851	67942	68033	92
48	68124	68214	68304	68394	68484	68574	68663	68752	68842	68930	90
49	69020	69108	69196	69284	69372	69460	69548	69635	69722	69810	88
50	69897	69983	70070	70156	70243	70329	70415	70500	70586	70671	86
51	70757	70842	70927	71011	71096	71180	71265	71349	71433	71516	84
52	71600	71683	71767	71850	71933	72015	72098	72181	72263	72345	82
53	72428	72509	72591	72672	72754	72835	72916	72997	73078	73158	81
54	73239	73319	73399	73480	73559	73639	73719	73798	73878	73957	80
55	74036	74115	74193	74272	74351	74429	74507	74585	74663	74741	78
56	74818	74896	74973	75050	75127	75204	75281	75358	75434	75511	77
57	75587	75663	75739	75815	75891	75966	76042	76117	76192	76267	75
58	76342	76417	76492	76566	76641	76715	76789	76863	76937	77011	74
59	77085	77158	77232	77305	77378	77451	77524	77597	77670	77742	73
60	77815	77887	77959	78031	78103	78175	78247	78318	78390	78461	72
61	78533	78604	78675	78746	78816	78887	78958	79028	79098	79169	71
62	79239	79309	79379	79448	79518	79588	79657	79726	79796	79865	70
63	79934	80002	80071	80140	80208	80277	80345	80413	80482	80550	69

* Each logarithm is supposed to have the decimal sign . before it.

LOGARITHMS OF NUMBERS FROM 0 TO 1000.

(Continued.)

No.	0	1	2	3	4	5	6	7	8	9	Prop.
64	80618	80685	80753	80821	80888	80956	81023	81090	81157	81224	68
65	81291	81358	81424	81491	81557	81624	81690	81756	81822	81888	67
66	81954	82020	82085	82151	82216	82282	82347	82412	82477	82542	66
67	82607	82672	82736	82801	82866	82930	82994	83058	83123	83187	65
68	83250	83314	83378	83442	83505	83569	83632	83695	83758	83821	64
69	83884	83947	84010	84073	84136	84198	84260	84323	84385	84447	63
70	84509	84571	84633	84695	84757	84818	84880	84941	85003	85064	62
71	85125	85187	85248	85309	85369	85430	85491	85551	85612	85672	61
72	85733	85793	85853	85913	85973	86033	86093	86153	86213	86272	60
73	86332	86391	86451	86510	86569	86628	86687	86746	86805	86864	59
74	86923	86981	87040	87098	87157	87215	87273	87332	87390	87448	58
75	87506	87564	87621	87679	87737	87794	87852	87909	87966	88024	57
76	88081	88138	88195	88252	88309	88366	88422	88479	88536	88592	56
77	88649	88705	88761	88818	88874	88930	88986	89042	89098	89153	56
78	89209	89265	89320	89376	89431	89487	89542	89597	89652	89707	55
79	89762	89817	89872	89927	89982	90036	90091	90145	90200	90254	54
80	90309	90363	90417	90471	90525	90579	90633	90687	90741	90794	54
81	90848	90902	90955	91009	91062	91115	91169	91222	91275	91328	53
82	91381	91434	91487	91540	91592	91645	91698	91750	91803	91855	53
83	91907	91960	92012	92064	92116	92168	92220	92272	92324	92376	52
84	92427	92479	92531	92582	92634	92685	92737	92788	92839	92890	51
85	92941	92993	93044	93095	93146	93196	93247	93298	93348	93399	51
86	93449	93500	93550	93601	93651	93701	93751	93802	93852	93902	50
87	93951	94001	94051	94101	94151	94200	94250	94300	94349	94398	49
88	94448	94497	94546	94596	94645	94694	94743	94792	94841	94890	49
89	94939	94987	95036	95085	95133	95182	95230	95279	95327	95376	48
90	95424	95472	95520	95568	95616	95664	95712	95760	95808	95856	48
91	95904	95951	95999	96047	96094	96142	96189	96236	96284	96331	48
92	96378	96426	96473	96520	96507	96614	96661	96708	96754	96801	47
93	96848	96895	96941	96988	97034	97081	97127	97174	97220	97266	47
94	97312	97359	97405	97451	97497	97543	97589	97635	97680	97726	46
95	97772	97818	97863	97909	97954	98000	98045	98091	98136	98181	46
96	98227	98272	98317	98362	98407	98452	98497	98542	98587	98632	45
97	98677	98721	98766	98811	98855	98900	98945	98989	99033	99078	45
98	99122	99166	99211	99255	99299	99343	99387	99431	99475	99519	44
99	99563	99607	99657	99694	99738	99782	99825	99869	99913	99956	44

HYPERBOLIC LOGARITHMS.

Hyperbolic logarithms is a system of logarithms so called because the numbers express the areas between the asymptote and curve of the hyperbola. The hyperbolic logarithm of any number is to the common logarithm of the same number in the ratio of 2·30258509 to 1, or as 1 to ·43429448.

TABLE
OF HYPERBOLIC LOGARITHMS.

Num.	Log.	Num.	Log.	Num.	Log.	Num.	Log.
1.01	.0099	1.43	.3576	1.85	.6151	2.27	.8197
1.02	.0198	1.44	.3646	1.86	.6205	2.28	.8241
1.03	.0295	1.45	.3715	1.87	.6259	2.29	.8285
1.04	.0392	1.46	.3784	1.88	.6312	2.30	.8329
1.05	.0487	1.47	.3852	1.89	.6365	2.31	.8372
1.06	.0582	1.48	.3920	1.90	.6418	2.32	.8415
1.07	.0676	1.49	.3987	1.91	.6471	2.33	.8458
1.08	.0769	1.50	.4054	1.92	.6523	2.34	.8501
1.09	.0861	1.51	.4121	1.93	.6575	2.35	.8544
1.10	.0953	1.52	.4187	1.94	.6626	2.36	.8586
1.11	.1043	1.53	.4252	1.95	.6678	2.37	.8628
1.12	.1133	1.54	.4317	1.96	.6729	2.38	.8671
1.13	.1222	1.55	.4382	1.97	.6780	2.39	.8712
1.14	.1310	1.56	.4446	1.98	.6830	2.40	.8754
1.15	.1397	1.57	.4510	1.99	.6881	2.41	.8796
1.16	.1484	1.58	.4574	2.00	.6931	2.42	.8837
1.17	.1570	1.59	.4637	2.01	.6981	2.43	.8878
1.18	.1655	1.60	.4700	2.02	.7030	2.44	.8919
1.19	.1739	1.61	.4762	2.03	.7080	2.45	.8960
1.20	.1823	1.62	.4824	2.04	.7129	2.46	.9001
1.21	.1962	1.63	.4885	2.05	.7178	2.47	.9042
1.22	.1988	1.64	.4946	2.06	.7227	2.48	.9082
1.23	.2070	1.65	.5007	2.07	.7275	2.49	.9122
1.24	.2151	1.66	.5068	2.08	.7323	2.50	.9162
1.25	.2231	1.67	.5128	2.09	.7371	2.51	.9202
1.26	.2341	1.68	.5187	2.10	.7419	2.52	.9242
1.27	.2390	1.69	.5247	2.11	.7466	2.53	.9282
1.28	.2468	1.70	.5306	2.12	.7514	2.54	.9321
1.29	.2546	1.71	.5364	2.13	.7561	2.55	.9360
1.30	.2623	1.72	.5423	2.14	.7608	2.56	.9400
1.31	.2700	1.73	.5481	2.15	.7654	2.57	.9439
1.32	.2776	1.74	.5538	2.16	.7701	2.58	.9477
1.33	.2851	1.75	.5596	2.17	.7747	2.59	.9516
1.34	.2926	1.76	.5653	2.18	.7793	2.60	.9555
1.35	.3001	1.77	.5709	2.19	.7839	2.61	.9593
1.36	.3074	1.78	.5766	2.20	.7884	2.62	.9631
1.37	.3148	1.79	.5822	2.21	.7929	2.63	.9669
1.38	.3220	1.80	.5877	2.22	.7975	2.64	.9707
1.39	.3293	1.81	.5933	2.23	.8021	2.65	.9745
1.40	.3364	1.82	.5988	2.24	.8064	2.66	.9783
1.41	.3435	1.83	.6043	2.25	.8109	2.67	.9820
1.42	.3506	1.84	.6097	2.26	.8153	2.68	.9858

TABLE—(Continued)

OF HYPERBOLIC LOGARITHMS.

Num.	Log.	Num.	Log.	Num.	Log.	Num.	Log.
2.69	.9895	3.11	1.1346	3.53	1.2612	3.95	1.3737
2.70	.9932	3.12	1.1378	3.54	1.2641	3.96	1.3726
2.71	.9969	3.13	1.1410	3.55	1.2669	3.97	1.3787
2.72	1.0006	3.14	1.1442	3.56	1.2697	3.98	1.3812
2.73	1.0043	3.15	1.1474	3.57	1.2725	3.99	1.3837
2.74	1.0079	3.16	1.1505	3.58	1.2753	4.00	1.3862
2.75	1.0116	3.17	1.1537	3.59	1.2781	4.01	1.3887
2.76	1.0152	3.18	1.1568	3.60	1.2809	4.02	1.3912
2.77	1.0188	3.19	1.1600	3.61	1.2837	4.03	1.3937
2.78	1.0224	3.20	1.1631	3.62	1.2864	4.04	1.3962
2.79	1.0260	3.21	1.1662	3.63	1.2892	4.05	1.3987
2.80	1.0296	3.22	1.1693	3.64	1.2919	4.06	1.4011
2.81	1.0331	3.23	1.1724	3.65	1.2947	4.07	1.4036
2.82	1.0367	3.24	1.1755	3.66	1.2974	4.08	1.4060
2.83	1.0402	3.25	1.1786	3.67	1.3001	4.09	1·4085
2.84	1.0438	3.26	1.1817	3.68	1.3029	4.10	1.4109
2.85	1.0473	3.27	1.1847	3.69	1.3056	4.11	1.4134
2.86	1.0508	3.28	1.1878	3.70	1.3083	4.12	1.4158
2.87	1.0543	3.29	1.1908	3.71	1.3110	4.13	1.4182
2.88	1.0577	3.30	1.1939	3.72	1.3137	4.14	1.4206
2.89	1.0612	3.31	1.1969	3.73	1.3164	4.15	1.4231
2.90	1.0647	3.32	1.1999	3.74	1.3190	4.16	1.4255
2.91	1.0681	3.33	1.2029	3.75	1.3217	4.17	1.4279
2.92	1.0715	3.34	1.2059	3.76	1.3244	4.18	1.4303
2.93	1.0750	3.35	1.2089	3.77	1.3271	4.19	1.4327
2.94	1.0784	3.36	1.2119	3.78	1.3297	4.20	1.4350
2.95	1.0818	3.37	1.2149	3.79	1.3323	4.21	1.4374
2.96	1.0851	3.38	1.2178	3.80	1.3350	4.22	1.4398
2.97	1.0885	3.39	1.2208	3.81	1.3376	4.23	1.4421
2.98	1.0919	3.40	1.2237	3.82	1.3402	4.24	1.4445
2.99	1.0952	3.41	1.2267	3.83	1.3428	4.25	1.4469
3.00	1.0986	3.42	1.2296	3.84	1.3454	4.26	1.4492
3.01	1.1019	3.43	1.2325	3.85	1.3480	4.27	1.4516
3.02	1.1052	3.44	1.2354	3.86	1.3506	4.28	1.4539
3.03	1.1085	3.45	1.2387	3.87	1.3532	4.29	1.4562
3.04	1.1118	3.46	1.2412	3.88	1.3558	4.30	1.4586
3.05	1.1151	3.47	1.2441	3.89	1.3584	4.31	1.4609
3.06	1.1184	3.48	1.2470	3.90	1.3609	4.32	1.4632
3.07	1.1216	3.49	1.2499	3.91	1.3635	4.33	1.4655
3.08	1.1249	3.50	1.2527	3.92	1.3660	4.34	1.4678
3.09	1.1281	3.51	1.2556	3.93	1.3686	4.35	1.4701
3.10	1.1314	3.52	1.2584	3.94	1.3711	4.36	1.4724

TABLE—(*Concluded*)

OF HYPERBOLIC LOGARITHMS.

Num.	Log.	Num.	Log.	Num.	Log.	Num.	Log.
4.37	1.4747	4.79	1.5665	5.21	1.6505	5.63	1.7281
4.38	1.4778	4.80	1.5686	5.22	1.6524	5.64	1.7298
4.39	1.4793	4.81	1.5706	5.23	1.6544	5.65	1.7316
4.40	1.4816	4.82	1.5727	5.24	1.6563	5.66	1.7334
4.41	1.4838	4.83	1.5748	5.25	1.6582	5.67	1.7351
4.42	1.4838	4.84	1.5769	5.26	1.6601	5.68	1.7369
4.43	1.4883	4.85	1.5789	5.27	1.6620	5.69	1.7387
4.44	1.4906	4.86	1.5810	5.28	1.6639	5.70	1.7404
4.45	1.4929	4.87	1.5830	5.29	1.6658	5.71	1.7422
4.46	1.4914	4.88	1.5851	5.30	1.6677	5.72	1.7439
4.47	1.4973	4.89	1.5870	5.31	1.6695	5.73	1.7457
4.48	1.4996	4.90	1.5892	5.32	1.6714	5.74	1.7474
4.49	1.5018	4.91	1.5912	5.33	1.6733	5.75	1.7491
4.50	1.5040	4.92	1.5933	5.34	1.6752	5.76	1.7509
4.51	1.5062	4.93	1.5953	5.35	1.6770	5.77	1.7526
4.52	1.5085	4.94	1.5973	5.36	1.6789	5.78	1.7544
4.53	1.5107	4.95	1.5993	5.37	1.6808	5.79	1.7561
4.54	1.5129	4.96	1.6014	5.38	1.6826	5.80	1.7578
4.55	1.5151	4.97	1.6034	5.39	1.6845	5.81	1.7595
4.56	1.5173	4.98	1.6054	5.40	1.6863	5.82	1.7613
4.57	1.5195	4.99	1.6074	5.41	1.6882	5.83	1.7630
4.58	1.5216	5.00	1.6094	5.42	1.6900	5.84	1.7647
4.59	1.5238	5.01	1.6114	5.43	1.6919	5.85	1.7664
4.60	1.5260	5.02	1.6134	5.44	1.6937	5.86	1.7681
4.61	1.5282	5.03	1.6154	5.45	1.6956	5.87	1.7698
4.62	1.5303	5.04	1.6174	5.46	1.6974	5.88	1.7715
4.63	1.5325	5.05	1.6193	5.47	1.6992	5.89	1.7732
4.64	1.5347	5.06	1.6213	5.48	1.7011	5.90	1.7749
4.65	1.5368	5.07	1.6233	5.49	1.7029	5.91	1.7766
4.66	1.5390	5.08	1.6253	5.50	1.7047	5.92	1.7783
4.67	1.5411	5.09	1.6272	5.51	1.7065	5.93	1.7800
4.68	1.5432	5.10	1.6292	5.52	1.7083	5.94	1.7817
4.69	1.5454	5.11	1.6311	5.53	1.7101	5.95	1.7833
4.70	1.5475	5.12	1.6331	5.54	1.7119	5.96	1.7850
4.71	1.5496	5.13	1.6351	5.55	1.7137	5.97	1.7867
4.72	1.5518	5.14	1.6370	5.56	1.7155	5.98	1.7884
4.73	1.5539	5.15	1.6389	5.57	1.7173	5.99	1.7900
4.74	1.5560	5.16	1.6409	5.58	1.7191	6.00	1.7917
4.75	1.5581	5.17	1.6428	5.59	1.7209	6.01	1.7934
4.76	1.5602	5.18	1.6448	5.60	1.7227	6.02	1.7950
4.77	1.5623	5.19	1.6463	5.61	1.7245	6.03	1.7967
4.78	1.5644	5.20	1.6486	5.62	1.7263	6.04	1.7989

RULES FOR FINDING THE ELASTICITY OF STEEL SPRINGS.

Rule 1.—*To find the Elasticity of a given Steel-plate Spring.*—Multiply the breadth of the plate in inches by the cube of the thickness in $\frac{1}{16}$ inch, and by the number of plates; divide the cube of the span in inches by the product so found, and multiply by 1.66. The result equals the elasticity in $\frac{1}{16}$ of an inch per ton of load.

Rule 2.—*To find Span due to a given Elasticity, and the Number and Size of Plate.*—Multiply the elasticity in sixteenths per ton, by the breadth of the plate in inches, and divide by the cube of the thickness in inches, and by the number of plates; divide by 1.66, and find the cube root of the quotient. The result equals the span in inches.

Rule 3.—*To find the Number of Plates due to a given Elasticity, also the Span and Size of the Plates.*—Multiply the cube of the span in inches by 1.66; multiply the elasticity in sixteenths by the breadth of the plate in inches, and by the cube of the thickness in sixteenths; divide the former product by the latter. The quotient is the number of plates.

Rule 4.—*To find the Working Strength of a given Steel-plate Spring.*—Multiply the breadth of plate in inches by the square of the thickness in sixteenths, and by the number of plates; multiply also the working span in inches by 11.3; divide the former product by the latter. The result equals the working strength in tons burden.

Rule 5.—*To find the Span due to a given Strength and the Number and Size of Plate.*—Multiply the breadth of the plate in inches by the square of the thickness in sixteenths, and by the number of plates; multiply, also, the strength in tons by 11.3, divide the former product by the latter. The result equals the working span in inches.

Rule 6.—*To find the Number of Plates due to a given Strength, Span, and Size of Plate.*—Multiply the strength in tons by span in inches, and divide by 11.3; multiply also the breadth of plate in inches by the square of the thickness in sixteenths; divide the former product by the latter. The result equals the number of plates.

TABLE

SHOWING THE ACTUAL EXTENSION OF WROUGHT-IRON AT VARIOUS TEMPERATURES.

Deg. of Fah.	Length.	
32°	1.	
212	1.0011356	
392	1.0025757	Surface becomes straw-colored, deep, yellow, crimson, violet, purple, deep blue, bright blue.
672	1.0043253	
752	1.0063894	
932	1.0087730	Surface becomes dull, and then bright red.
1112	1.0114811	
1652	1.0216024	Bright red, yellow, welding heat, white heat.
2192	1.0348242	
2732	1.0512815	
2912	Cohesion destroyed. Fusion perfect.	

Linear Expansion of Wrought-iron.—The linear expansion a bar of wrought-iron undergoes, according to Daniell's pyrometer, when heated from the freezing- to the boiling-point, or from 32° to 212° Fah., is about $\frac{1}{880}$ of its length; at higher temperatures, the elongation becomes more rapid. Thus, it will be seen how sensible a change takes place when iron undergoes a variation of temperature. A bar of iron, 10 feet long, subject to an ordinary change of temperature of from 32° to 180° Fah., will elongate more than $\frac{1}{8}$ of an inch, or sufficient to cause fracture in stone work, strip the thread of a screw, or endanger a bridge, floor, roof, or truss.

The expansion of volume and surface of wrought-iron

is calculated by taking the linear expansion as unity; then, following the geometrical law, the superficial expansion is twice the linear, and the cubical expansion is three times the linear.

Wrought-iron will bear on a square inch, without permanent alteration, 17,800 pounds, and an extension in length of $\frac{1}{1400}$. Cohesive force is diminished $\frac{1}{3000}$ by an increase of 1 degree of heat.

Compared with cast-iron, its strength is 1.12 times, its extensibility 0.86 times, and its stiffness 1.3 times.

Cast-iron expands $\frac{1}{162000}$ of its length for 1 degree of heat; the greatest change in the shade, in this climate, is $\frac{1}{1170}$ of its length; exposed to the sun's rays, $\frac{1}{1000}$.

Cast-iron shrinks, in cooling, from $\frac{1}{85}$ to $\frac{1}{98}$ of its length.

Cast-iron is crushed by a force of 93,000 pounds upon a square inch, and will bear, without permanent alteration, 15,300 pounds upon a square inch.

TABLE

DEDUCED FROM EXPERIMENTS ON IRON PLATES FOR STEAM BOILERS, BY THE FRANKLIN INSTITUTE, PHILADA.

Iron boiler-plate was found to increase in tenacity as its temperature was raised, until it reached a temperature of 550° above the freezing-point, at which point its tenacity began to diminish.

At	32° to 80°	tenacity is	56,000 lbs.,	or one-seventh below its maximum.
"	570°	" "	66,000 "	the maximum.
"	720°	" "	55,000 "	the same nearly as at 30°.
"	1050°	" "	32,000 "	nearly one-half the maximum.
"	1240°	" "	22,000 "	nearly one-third the maximum.
"	1317°	" "	9,000 "	nearly one-seventh the maximum.

It will be seen by the above table that if a boiler should become overheated, by the accumulation of scale on some

of its parts or an insufficiency of water, the iron would soon become reduced to less than one-half its strength.

TABLE

SHOWING THE RESULT OF EXPERIMENTS MADE ON DIFFERENT BRANDS OF BOILER IRON AT THE STEVENS INSTITUTE OF TECHNOLOGY, HOBOKEN, N. J.

Thirty-three experiments were made upon the iron taken from the exploded steam-boiler of the ferry-boat Westfield. The following were the results:

	Lbs. per sq. inch.
Average breaking weight	41,653
16 experiments made upon high grades of American boiler-plate.	
Average breaking weight	54,123
15 experiments made upon high grades of American flange-iron.	
Average breaking weight	42,144
6 experiments made upon English Bessemer steel.	
Average breaking weight	82,621
5 experiments made upon English Lowmoor boiler-plate.	
Average breaking weight	58,984
6 experiments made upon samples of tank-iron from different manufacturers.	
Average breaking weight No. 1	43,831
" " " No. 2	42,011
" " " No. 3	41,249
2 experiments made on iron taken from the exploded steam-boiler of the Red-Jacket.	
Average breaking weight	49,000

It will be noticed that the above experiments reveal a great variation in the strength of boiler-plate of different grades of iron, and furnish conclusive evidence that the tensile strength of boiler-iron ought to be taken at 50,000 pounds to the square inch, instead of 60,000.

TABLES

SHOWING THE WEIGHT OF CAST-IRON BALLS FROM 3 TO 13 INCHES IN DIAMETER.

Diameter in inches..	3	3¼	3½	3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6	6¼	6½	6¾	7	7¼	7½	7¾
Weight in pounds....	3¾	4¾	5¾	7¼	8¾	10½	12½	14¾	17	20	23	26	29¾	33½	37¾	42¼	47¼	52½	58	64

Diameter in inches..	8	8¼	8½	8¾	9	9¼	9½	9¾	10	10¼	10½	10¾	11	11½	12	13
Weight in pounds....	70½	77¼	84¼	92½	100¼	109	118	127½	137¾	148¼	159½	171	183¼	209½	238	302

WEIGHT OF CAST-IRON PLATES PER SUPERFICIAL FOOT AS PER THICKNESS.

Thickness in inches.........	⅛	¼	⅜	½	⅝	¾	⅞	1
Weight.........................	lbs. oz. 4 13	lbs. oz. 9 10	lbs. oz. 14 8	lbs. oz. 19 5	lbs. oz. 24 2	lbs. oz. 29 0	lbs. oz. 33 13	lbs. oz. 38 10

TABLE

SHOWING THE WEIGHT OF CAST-IRON PIPES, 1 FOOT IN LENGTH, FROM ¼ INCH TO 1¼ INCHES THICK, AND FROM 3 TO 24 INCHES DIAMETER.

Diameter of Bore in Inches.	Thickness in Inches.								
	¼ Lbs.	⅜ Lbs.	½ Lbs.	⅝ Lbs.	¾ Lbs.	⅞ Lbs.	1 Lbs.	1⅛ Lbs.	1¼ Lbs.
3	8½	12½	17¼	22¼	27½	....	....	....	....
3½	9¼	14¼	19½	25¼	31¼	....	....	....	....
4	10	16¾	22	28½	35	....	....	....	....
4½	11¾	18	24½	31½	38¾	....	....	....	....
5	13	19¾	27	34½	42¼	50½	59	....	....
5½	15	21½	29½	37½	46	54¾	63¾	....	....
6	....	23½	32	40¾	49¾	59	68¾	78¾	88¾
6½	....	25¼	34½	43¾	53½	63½	73½	84¼	95
7	....	27¼	36¾	46¾	56¾	67¾	78½	89¾	101¼
7½	....	29	39	50	60¾	72	83½	95¼	107½
8	....	30¾	41¾	53	64½	76¼	88½	100¾	113½
8½	....	33	44½	56¼	68¼	80¾	93½	106½	120
9	....	34½	46½	59	71¾	84¾	98½	111¾	125¾
9½	....	36¼	49	62	75½	89	103	117½	132
10	....	38¼	51½	65¼	79¼	93½	108	122¾	138
10½	....	....	54	68¼	82¾	97¾	112¾	128½	144¼
11	....	....	56½	71¼	86½	102	117¾	134	150¼
11½	....	....	59	76¼	90	106¼	122¾	139½	156½
12	....	....	61¼	77½	93½	110½	127½	145	162½
13	....	....	....	82¾	101¼	118¼	137½	154	173½
14	....	....	....	89¼	108¼	126½	146¼	165¼	185¼
15	....	....	....	95¼	115¾	135¼	156¼	176¼	198
16	....	....	....	....	123¼	143	166	187½	211¼
17	....	....	....	....	130¼	152½	178½	198¼	223½
18	....	....	....	....	137	161¼	185¼	209	235¼
19	....	....	....	....	....	169¼	195¾	222¼	247
20	....	....	....	....	....	178	205¼	233¼	259
21	....	....	....	....	....	....	214	243½	273¼
22	....	....	....	....	....	....	223½	244¾	285¼
23	....	....	....	....	....	....	233½	265½	298¼
24	....	....	....	....	....	....	245¼	277½	310½

TABLE

SHOWING THE WEIGHT OF BOILER-PLATES 1 FOOT SQUARE, AND FROM $\frac{1}{16}$TH TO AN INCH THICK.

Thickness in inches.............	$\frac{1}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
Weight in lbs. per foot sq......	$2\frac{1}{2}$	5	$7\frac{1}{2}$	10	$12\frac{1}{2}$	15	$17\frac{1}{2}$	20	$22\frac{1}{2}$	25	$27\frac{1}{2}$	30	$32\frac{1}{2}$	35	$37\frac{1}{2}$	40

TABLE

SHOWING THE WEIGHT OF SQUARE BAR-IRON, FROM $\frac{1}{2}$ AN INCH TO 6 INCHES SQUARE, 1 FOOT LONG.

Square...........	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{8}$	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$	3	$3\frac{1}{8}$
Weight in lbs...	$\frac{8}{10}$	$1\frac{1}{4}$	2	$2\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{4}$	$5\frac{1}{4}$	$6\frac{1}{2}$	$7\frac{1}{2}$	9	$10\frac{1}{2}$	12	$13\frac{1}{2}$	$15\frac{1}{4}$	17	19	22	$23\frac{1}{4}$	$25\frac{1}{2}$	28	$30\frac{1}{2}$	33

Square.........	$3\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{3}{4}$	$3\frac{7}{8}$	4	$4\frac{1}{8}$	$4\frac{1}{4}$	$4\frac{3}{8}$	$4\frac{1}{2}$	$4\frac{5}{8}$	$4\frac{3}{4}$	$4\frac{7}{8}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$	6
Weight in lbs.	$35\frac{3}{4}$	$38\frac{1}{2}$	$41\frac{1}{2}$	$44\frac{1}{2}$	$47\frac{1}{2}$	$50\frac{3}{4}$	54	$57\frac{1}{2}$	61	$64\frac{3}{4}$	$68\frac{1}{2}$	$72\frac{1}{4}$	$76\frac{1}{4}$	$80\frac{1}{4}$	$84\frac{1}{2}$	$93\frac{1}{4}$	$102\frac{1}{4}$	$111\frac{3}{4}$	$121\frac{3}{4}$

TABLE

SHOWING THE WEIGHT OF ROUND-IRON FROM $\frac{1}{2}$ AN INCH TO 6 INCHES DIAMETER, 1 FOOT LONG.

For Calculating the Weight of Shafting, etc.

Diameter in inches............	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{8}$
Weight in pounds..............	$\frac{3}{4}$	1	$1\frac{1}{2}$	2	$2\frac{3}{4}$	$3\frac{1}{2}$	$4\frac{1}{4}$	5	6	7	8	$9\frac{1}{2}$	$10\frac{1}{2}$	12

Diameter in inches............	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{1}{2}$	$2\frac{5}{8}$	$2\frac{3}{4}$	$2\frac{7}{8}$	3	$3\frac{1}{8}$	$3\frac{1}{4}$	$3\frac{3}{8}$	$3\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{3}{4}$	$3\frac{7}{8}$
Weight in pounds..............	$13\frac{1}{2}$	15	$16\frac{3}{4}$	$18\frac{1}{4}$	20	22	24	26	28	$30\frac{1}{4}$	$32\frac{1}{2}$	35	$37\frac{1}{4}$	40

Diameter in inches.	4	$4\frac{1}{8}$	$4\frac{1}{4}$	$4\frac{3}{8}$	$4\frac{1}{2}$	$4\frac{5}{8}$	$4\frac{3}{4}$	$4\frac{7}{8}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$	6
Weight in pounds..............	$42\frac{1}{2}$	$45\frac{1}{4}$	48	$50\frac{3}{4}$	$53\frac{3}{4}$	$56\frac{3}{4}$	60	63	$66\frac{3}{4}$	$73\frac{1}{4}$	$80\frac{1}{4}$	$87\frac{3}{4}$	$95\frac{1}{2}$

HOW TO MARK ENGINEERS' OR MACHINISTS' TOOLS.

Any engineer or machinist can mark his name on his tools by first warming the tool to be marked, and rubbing on a thin layer of beeswax or tallow until it flows, and then letting it cool; after which the name may be marked with a dull scriber or a piece of hard wood sharpened to a point; then, by applying some nitric acid for a few minutes, the name will be found etched on the steel; after which the acid must be thoroughly washed off with water, and the tool again heated in order to remove the wax or tallow, and rubbed over with a soft rag.

TO POLISH BRASS.

Engineers will find the following recipe a good one for polishing the brass work of their engines. Oxalic acid, dissolved in rain- or cistern-water, in the proportion of about five cents' worth to a pint of water, if applied with a rag or piece of waste, will remove the tarnish from brass, and render it bright; the surface should then be rubbed with an oily rag and dried, and afterwards burnished with chalk, whiting, or rotten-stone. This is probably one of the quickest known methods for cleaning brass. A mixture of muriatic acid and alum, dissolved in water, imparts a golden color to brass articles that are steeped in it for a few seconds.

Owing to irregularities of surface, it often happens that considerable difficulty is encountered in putting a good polish on articles of brass or copper. If, however, they be immersed in a bath composed of aqua-fortis, 1 part; spirits of salt, 6 parts; and water, 2 parts, for a few minutes, if small, or about half an hour if large, they

will become covered with a kind of black mud, which, on removal by rinsing, displays a beautiful lustrous under-surface. Should the lustre be deemed insufficient, the immersion may be repeated, care always being taken to rinse thoroughly. All articles cleaned in this manner should be dried in hot, dry sawdust.

Another receipt for cleaning brass, nickel-plated ware, or German silver, is to dissolve one ounce of carbonate of ammonia in four ounces of water, after which it should be mixed with 16 ounces of Paris white. To apply it, moisten a sponge with water, dip it in the powder, rub quickly and lightly over the surface of the metal, after which it may be rubbed over with some of the dry powder on a soft cloth or piece of clean waste.

SOLDER.

The following solder will braze steel or iron, and may be found very useful in case of a valve-stem or other light portion of an engine or machine breaking at a time when it is important that the engine or machine should continue work: Silver, 19 parts; copper, 1 part; brass, 2 parts. If practicable, charcoal dust should be strewed over the melted metal in the crucible.

CEMENT FOR MAKING STEAM-JOINTS AND PATCHING STEAM-BOILERS.

Take a quantity of pure red-lead, put it in an iron mortar, on a block or thick plate of iron. Put in a quantity of white-lead ground in oil; knead them together until you make a thick putty; then pound it; the more it is pounded, the softer it will become. Roll in red-lead and pound again; repeat the operation, adding red-lead,

and pounding until the mass becomes a good stiff putty. In applying it to the flange or joint, it is well to put a thin grummet around the orifice of the pipe, to prevent the cement being forced inward to the pipe when the bolts are screwed up. When the flanges are not faced, make the above mass rather soft, and add cast-iron borings run through a fine sieve, when it will be found to resist either fire or water.

Another Cement.—Powdered litharge, 2 parts; very fine sand, 2 parts; slacked quick-lime, 1 part. Mix all together. So use; mix the proper quantity with boiled linseed-oil, and apply quick. It gets hard very soon.

Another Cement.—White-lead ground in oil, 10 parts; black oxide of manganese, 3 parts; litharge, 1 part. Reduce to the proper consistency with boiled linseed-oil, and apply.

Another Cement.—Red-lead ground in oil, 6 parts; white-lead, 3 parts; oxide of manganese, 2 parts; silicate of soda, 1 part; litharge, ½ part; all mixed and used as putty.

Another Cement.—Take 10 pounds of ground litharge, 4 pounds of ground Paris white, ½ pound of yellow ochre, and ½ ounce of hemp; cut into lengths of ½ inch; mix all together with boiled linseed-oil, to the consistency of a stiff putty. This cement resists fire, and will set in water.

Cement for Rust-Joints.—Cast-iron borings or turnings, 19 pounds; pulverized sal-ammoniac, 1 pound; flour of sulphur, ½ pound. Should be thoroughly mixed and passed through a tolerably fine sieve. Sufficient water should be added to wet the mixture through. It should be prepared some hours before being used. A small quantity of sludge from the trough of a grinding-stone will improve its quality.

JOINTS.

Rust-joints, composed of sal-ammoniac, iron borings, flour of sulphur, and water, were formerly employed for all the permanent joints around engines; but they are fast going out of use and being replaced by faced joints.

Red-lead joints were also very generally used, but they are now obsolete, and justly so, not only for their dirty appearance, but also for the difficulty experienced in starting them, as it required, in most cases, the use of sledges and chisels, which incurred the danger of breaking the flanges.

All movable joints of the best description of land and marine engines are now faced on a lathe or planer, and then rendered perfectly steam-, air-, and water-tight, by filing and scraping, so that all that is necessary, when put together, is to oil their surfaces.

For smooth surfaces that can be conveniently calked, sheet copper, annealed by heating it to a cherry red, and then plunging it in cold water, makes a permanent joint.

Lead wire makes a very cheap, clean, and permanent joint. Copper wire also makes a very good joint; but, when convenient, it is always best to plane or turn a groove in one of the surfaces to be brought in contact.

For uniform surfaces, gauze wire-cloth, coated on either side with white- or red-lead paint, makes a very durable joint, particularly where it is exposed to high temperatures.

For pumps or stand-pipes in the holds of vessels, canvas well saturated on both sides with white- or red-lead makes a very durable joint. Pasteboard painted on both sides with white- or red-lead paint is frequently used with good results.

RELATIVE VALUE OF FOREIGN AND UNITED STATES MONEY.

Country.	Monetary Unit.	Standard.	Value in U. States money of account.
Argentine Rep..	Peso fuerte..............	Gold..............	0 98.37
Austria	Florin....................	Silver.......... ...	47.60
Belgium..........	Franc.....................	Gold and silver	19.30
Bolivia...........	Dollar*..................	Silver......... ...	96.50
Brazil.............	Milreis of 1000 reis....	Gold.....	54.56
Canada...........	Dollar....................	Gold.........	1 00.00
Cent'l America.	Dollar.................	Silver	95.50
Chili...............	Peso	Gold and silver	91.34
China.............	Cash..............	Copper..........	
Cuba..............	Peso......................	Gold.........	92.58
Denmark	Rigsdaler.................	Silver......... ...	96.50
Ecuador..........	Dollar....................	Silver	96.50
Egypt.............	Dollar of 20 piastres..	Silver......... ...	1 00.39
France	Franc.....................	Gold and silver	19.30
Great Britain...	Pound sterling.........	Gold..............	4 86.65
Greece............	Drachms.................	Silver......	19.30
German Empire	Mark	Gold..............	23.82
Hayti.........	Dollar.....................	Silver......... ...	1 00.00
Jamaica..........	Pound sterling.........	Gold..............	4 86.65
Japan.............	Yen........................	Gold......	99.97
India..............	Rupee of 16 ounces...	Silver...	45.84
Italy...............	Lira.......................	Gold and silver	19.30
Liberia...........	Dollar....................	Gold.......... ...	1 00.00
Mexico...........	Dollar...............	Silver......	1 04.75
Netherlands.....	Guilder..................	Silver......	40.50
Norway...........	Rigsdaler of 120 skgs.	Gold......	1 07.20
Paraguay	Peso	Gold............ ..	98.37
Peru........	Dollar....................	Silver......	96.50
Porto Rico........	Peso......................	Gold......	92.58
Portugal..........	Milreis of 1000 reis....	Gold............ ..	1 08.47
Russia	Roubles 100 copecks..	Silver......	77.17
Sandwich Isl'ds	Dollar....................	Gold.....	1 00.00
Spain..............	Peseta, 100 centimes...	Gold and silver	19.30
Sweden...........	Riksdaler of 100 oere.	Silver......	27.34
Switzerland......	Franc.....................	Gold and silver	19.30
Tripoli............	Mahbub of 20 piastres	Silver......... ...	87.09
Tunis..............	Piastre of 16 caroubs..	Silver......	12.50
Turkey...........	Piastre....................	Gold......	04.39
U.S.of Columbia	Peso......................	Silver......	96.50
Uruguay.........	Patacon..................	Gold......	94.98
Venezuela.......	Peso......................	Silver......	77.73

* The name Dollar is derived from the German "thaler," or from the Swedish "rixdale," royal dollar. The sign $ was adopted as a matter of convenience, instead of the U. S., which was formerly used.

TABLE

SHOWING THE LOAD THAT CAN BE CARRIED BY MAN AND ANIMALS.

Carriers.	Kind of Road.	Load in Lbs.	Feet per Second.	Hrs. per Day.	Miles.
Man	Good level	100	3	7	14.3
Man	Ordinary	95	2.5	7	12
Man	Mountainous	50	3.5	10	23.8
Llama of Peru	Mountainous	100	3.5	10	23.8
Donkey	Good level	300	3.5	10	23.8
Donkey	Mountainous	200	3.5	10	23.8
Mule	Good level	500	5.0	10	34
Mule	Mountainous	400	4.5	10	40.6
Horse	Good level	300	6	8	32.7
Horse	Mountainous	300	4.5	8	24.5
Camel	Deserts	1000	3 to 4	12	30 to 40
Elephant	Ordinary	1800	3 to 4	10	35

MAN OR ANIMAL WORKING-MACHINE.

Man or Animal.	Machine.	Force in Lbs.	Ft. per Second.	Hrs. per Day.
Man	Rope and pulley	50	0.8	6
Man	Crank	20	2.5	8
Man	Tread-wheel	144	0.5	8
Man	Tread-wheel	30	2.5	8
Man	Draws or pushes	30	2	8
Horse	Horse-mill	106	3	8
Horse	Horse-mill	72	9	5
Horse	Four-wheel carriage	154	3	10
Horse	Revolving mill platform.	100	3	8
Mule	Revolving mill platform.	66	3	8
Ass	Revolving mill platform.	33	3	8

TABLE

OF COEFFICIENTS OF FRICTIONS BETWEEN PLANE SURFACES.

Sliding Surface.	Surface at Rest.	State of the Surfaces.		Coefficient of Friction.
Cast-iron.	Wrought-iron.	Fibres of both surfaces parallel to motion.	Surfaces unctuous.	0.143
			Without lubric.	0.152
			Surfaces unctuous.	0.144
Cast-iron.	Cast-iron.	" "	Lubricated with tallow.	0.100
			Lubricated with lard.	0.070
			Lubricated with olive-oil.	0.060
			Lubricated with lard and pl'bago.	0.055
Wrought-iron.	Bronze.	Fibres parallel to motion.	Without lubric.	0.072
			Surfaces unctuous.	0.060
			Lubricated with tallow.	0.103
			Lubricated with lard.	0.075
			Lubricated with olive-oil.	0.078
Bronze.	Wrought-iron.	" "	Without lubric.	0.161
			Surfaces unctuous.	0.166
			Lubricated with tallow.	0.081
			Lubricated with lard and pl'bago.	0.089
			Lubricated with olive-oil.	0.072
Cast-iron.	Bronze.	" "	Without lubric.	0.147
			Surfaces unctuous.	0.132
			Lubricated with tallow.	0.103
			Lubricated with lard.	0.075
			Lubricated with olive-oil.	0.078
Bronze.	Cast-iron.	" "	Without lubric.	0.217
			Surfaces unctuous.	0.107
			Lubricated with tallow.	0.086
			Lubricated with olive-oil.	0.077
Bronze.	Bronze.	" "	Without lubric.	0.201
			Surfaces unctuous.	0.134
			Lubricated with olive-oil.	0.058
Brass.	Cast-iron.	" "	Without lubric.	0.189
			Surfaces unctuous.	0.115
			Lubricated with tallow.	0.072
			Lubricated with lard.	0.068
			Lubricated with olive-oil.	0.066
Steel.	Cast-iron.	" "	Without lubric.	0.202
			Lubricated with tallow.	0.105
			Lubricated with lard.	0.081
			Lubricated with olive-oil.	0.079

TABLE—(*Continued.*)

OF COEFFICIENTS OF FRICTIONS BETWEEN PLANE SURFACES.

Sliding Surface.	Surface at Rest.	State of the Surfaces.			Coefficient of Friction.
Steel.	Wrought-iron.	Fibres of iron parallel to motion.	Lubricated with	tallow.	0.093
				lard.	0.076
			Without lubric.		0.152
Steel.	Bronze.		Lubricated with	tallow.	0.056
				olive-oil.	0.053
				lard and pl'bago.	0.076

The work expended on friction is generally converted into heat, which is not utilized, but lost. It is, therefore, of great importance, in the working of machinery, to reduce the work of friction to the lowest possible amount; for which reason lubricating substances are introduced between the friction surfaces, such as powdered graphite, oil, tallow, lard, and, in fact, almost all kinds of fatty substances; all of which reduce the friction coefficients, but to a different degree, depending on how and on what kind of surfaces the lubrication is used. The friction coefficient is independent of the extent of areas in contact until near the point of abrasion.

The force of friction can be ascertained only by experiments which have been made by Columbo, Vince, and Rennie; but the most complete and reliable experiments on friction were made by Morin, at the expense of the French government.

TABLE

OF FRICTION COEFFICIENTS FOR DIFFERENT PRESSURES UP TO THE LIMIT OF ABRASION.

Pressure per Square Inch.	Wrought-iron upon Wrought-iron.	Wrought-iron upon Cast-iron.	Steel upon Cast-iron.	Brass upon Cast-iron.
32.5	0.140	0.174	0.166	0.157
187	0.250	0.275	0.300	0.255
240	0.271	0.292	0.233	0.219
277	0.285	0.320	0.340	0.214
315	0.297	0.329	0.344	0.211
336	0.312	0.333	0.347	0.215
373	0.350	0.351	0.351	0.206
411	0.376	0.353	0.353	0.205
448	0.395	0.365	0.354	0.208
485	0.403	0.366	0.356	0.221
523	0.409	0.366	0.357	0.223
560	Abrasion.	0.367	0.358	0.233
597		0.367	0.359	0.234
635		0.367	0.367	0.235
672		0.376	0.403	0.233
709		0.434	Abrasion.	0.234
747		Abrasion.		0.235
784				0.232
821				0.273

THE PREVENTION AND REMOVAL OF SCALE IN STEAM BOILERS.

There is no subject in connection with the use of steam of so much importance as that of the prevention of deterioration of boilers from the injurious effects resulting from an accumulation of scale on the interior surfaces, and from the use of feed waters containing chemical ingredients, which attack the iron, producing some one of the numerous forms of corrosion, and to which causes, no doubt, are due many disastrous explosions, entailing great loss of life and property; but under more favorable conditions, which, though not culminating disastrously, nevertheless add considerably to the cost in producing the required power.

Lord's Compound, a chemical preparation, has been used successfully for many years by more than twenty thousand representative establishments throughout the United States and Canada, and is highly recommended for neutralizing the acids in feed waters, and also for the prevention and removal of scaly deposits, without in any manner injuring the material of the boiler.

This compound is manufactured dry, in the form of a granulated powder, in appearance resembling common brown sugar, and is put up in packages of convenient size—half barrels, barrels, and casks—covering a wide range in weight, of from twenty-five to five hundred pounds, for the convenience of large and small consumers. It readily dissolves in water, and can therefore be applied in a dry state through the man-hole, or in a liquid state by the feed pump, whichever is most convenient.

The quantity for an application will depend upon the nature and amount of water evaporated, the composition

of the scale, the construction of the boiler, etc., but for general use a half pound per horse-power per month has been found to give satisfactory results.

It is important in all cases to remove the man- and hand-hole covers at stated intervals, clean out the sediment which is sure to accumulate under all circumstances on the bottom of the boiler, subjecting it to the liability of overheating, and probably rupture; but it is imperatively necessary to be awake to this important duty when using "Lord's Compound," as the scale on the tubes and upper portions of the boiler being detached by it, is in time precipitated to the bottom, increasing the accumulation there and also the danger of overheating, if, as in many cases, the fire is in direct contact with it.

When judiciously applied, this compound will never fail to meet the most sanguine expectations of the purchaser, but being composed of chemicals which are harmless to boiler material, its action may require a longer period than would be needed by many of the dangerous and worthless compounds made of refuse acids, which, while removing the scale, likewise destroy the boiler iron by their corrosive action.

Lord's Compound is probably the only one of its kind that is unanimously endorsed by professional men throughout the length and breadth of this continent, among whom are authors of mechanical books, engineers in charge of works, practical chemists, professional inspectors, and manufacturers having large capital invested in steam boilers. This unanimous endorsement is probably due to the fact that not a single accident has occurred to any boiler using his compound, although they are to be found in every steam-using locality from Canada to Mexico, and from Maine to the Pacific slope. No stronger recommendation of its merits can be given.

INDEX.

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